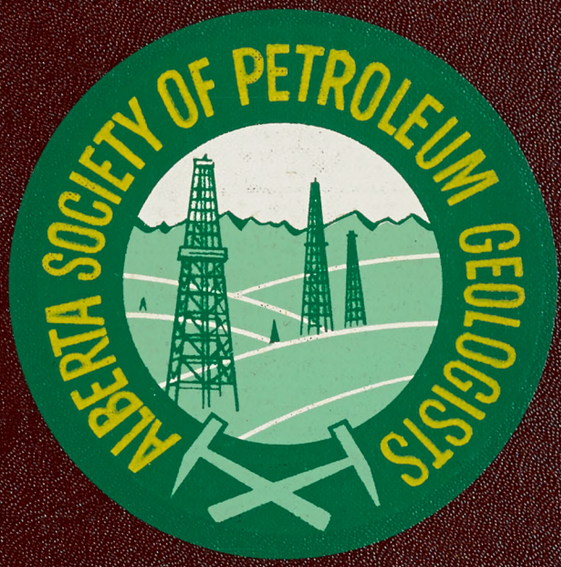
GUIDE BOOK

Sixth Annual Field Conference



BOW VALLEY

August 1956

GUIDE BOOK

A. C. Steeves.
LVIII

Sixth Annual
Field Conference

BOW VALLEY

August, 1956



FRONTISPIECE

Southeast end of Mount Rundle above road from Canmore to Spray Lakes. Light grey bedded dolomites of Southesk formation resting on massive black dolomite of Cairn formation. (Geological Survey of Canada photograph).

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For technical assistance, we thank Schlumberger Well Surveying Corporation.

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PREFACE

In choosing the Bow River Valley and its environs for study at its sixth annual conference, the Alberta Society of Petroleum Geologists has elected to follow in the footsteps of many men, of whom a few were remarkable. The Bow Valley has been travelled by Indians for many generations and by white men for a little more than two hundred years. These white men, all assembled together, would be a notably motley crowd. Traders would be there, and adventurers, soldiers and hunters, missionaries and scientists, thieves and vagabonds, and, of special interest to us, geologists would be there

To list the names of all these geologists would be impossible, and in any event, those whose observations have been published should be known at least to every western Canadian student. However, three are especially deserving of mention, because they did their work at a very early stage in the development of the country. Hector was the first, arriving in 1858 with Captain John Palliser's party of explorers. Hector was perhaps the most optimistic geologist ever to come to this region — he was not overawed by the geology and was evidently prepared to solve the problems. (See Bow Valley Sketches, p. 1). A few years later, in the eighteen eighties, R. G. McConnell, one of the great men of Canadian geology, travelled and worked here. We have McConnell to thank for the first workable subdvision of our Palaeozic section, and it is a measure of his worth that, although we have refined his classification, we have never eliminated any part of it. At the turn of the century, D. B. Dowling was engaged in study of the coal resources — a monumental work that was to occupy a large part of his life.

Since about 1900 many officers of the Geological Survey of Canada have contributed to the literature on the region. Also, geologists of the Research Council of Alberta, of the faculties of several universities, and of many companies have reported on various facets of Bow River geology.

With all this attention, numerous problems remain unsolved. It is taking a little longer to unravel the details of stratigraphy and structure than Hector anticipated. However, we are making steady progress, and it is the belief of the editors that the papers in this book bring us a little nearer to some of the answers.

Seven of the papers are devoted to discussion of stratigraphy and stratigraphic problems, three are discourses on structural problems, two are concerned with economic geology, and one with the development of hydroelectric power in the Bow River drainage basin. Our custom in the past has been to present at the beginning of each Guide Book a brief sketch of the human history of the area being studied. This is an agreeable custom and it has been observed in this book.

The reader may wonder at the random arrangement of the papers. It was originally intended that the stratigraphic papers should appear in order after the historical introduction, and that the structural and other papers should be grouped in the second half of the book. In the end it became necessary to take the papers, with one or two exceptions, as they became available from the printer in final form.

The editors and the society in general hope that this Guide Book will be a useful and valued part of every geologist's library.

F. G. Fox

A. M. Patterson

BOW VALLEY SKETCHES

W. B. GALLUP[1]

Early adventurers to the west remarked that on the prairies there are valleys but no hills. So it is with the Bow River east of the foothills. The great river cuts across the plains in a wide valley rimrocked by the Paleocene and impeded by the Pleistocene. Its meandering channel on the floor of the valley is not quite compatible with the youthfulness of the valley topography. However, the physiography of the Bow is a subject for a different essay. This discussion concerns the very recent adventures of man along the valley and its upper tributaries.

Not far above the village of Cochrane, (about 5 miles), the Bow leaves the foothills to cross the Alberta Syncline and so to the Plains. The general region is well watered, the tributaries are many. For two hundred miles below the mountains the Bow (Nama)[2] and its sisters, the Highwood (Spitzee)[2], and the Old Man (Stomuks-ki-piskun)[2], are the factors controlling the topography, economy and sociology.

The plains are barren of all but grass, scrub brush, and isolated poplar bluffs. The river and its tributaries are hospitable to somewhat better growth. The grass is longer in and adjacent to the stream valleys. The poplars are larger and what is more important, the chokecherry and the Saskatoon flourish in its vicinity. The two latter make excellent bow and arrow material. The course of our river below the mountains was the arsenal of the plains tribes – hence the Bow River.

One occasionally reads in historical fiction of how the plains tribes adjacent to the mountains hereabouts told early explorers of even earlier visits by bearded white men from the west, the inference being that these were Russians digressing from their Pacific adventures. This is a tale fascinating to contemplate but unsupported in fact.

The first white man of record to approach the region was Anthony Henday, who wintered about 100 miles northeast of Calgary with about 300 lodges of Blood[3] (Kainai) Indians in 1754. Henday's mission was to entice the Blackfoot to trade at Hudson's Bay. These people, already having all any man ever needed, were not enticed by his beads and cloth and politely refused his offer of trade in a strange land. Henday returned glowing with their hospitality and was laughed out of the service of the Company[4] for his tales of mounted Indians[5].

It is possible that other adventurers were about in Henday's time. There is a legend of a "Fort Jonquiere" somewhere near the present site of Calgary, not long before Henday's time. This is probably due to inaccuracies in the accounts of 'Canadien' canoe men sent to establish a fort up the South Saskatchewan River (then including the Bow). These "hommes de pays haut" probably smoked fast burning tobacco[6]; their claim of establishing a fort near where Calgary now stands is not established. However, it was given some authenticity by a Royal Northwest Mounted Police officer in later years.

[1] Consulting Geologist, Gallup, Buckland & Farney Ltd.

[2] The Terms are Blackfoot:

Nama – Weapon.

Spitzee – Highwood.

Stomuks-ki-piskun – In brief, "The bull pen", in fact "The place where we made the trap for the white bull and he got away". The name Old Man may be of other than Blackfoot origin, or of earlier account, "Napi" is the "Old Man" of Blackfoot mythology.

[3] "Blood" is a modern appellation of Kainai – "every man a chief" denotes a branch of the Blackfoot Nation, the name being derived from the mythology of that tribe.

[4] The Hudson's Bay Company, then beginning to expand their commerce westward from the Bay.

[5] The horse was then a newcomer to the plains of Alberta, probably having arrived about 25 years before Henday's visit.

[6] Distance was measured a pipe to a league.

In any land it is men of understanding who leave their mark. So it was with Henday, who enjoyed his visit with the Bloods so well. Unfortunately, circumstances did not allow him to remain. However, it is probable that his blood remains in the people of the northern Blackfeet whom he admired so much.

The next "man of understanding" was David Thompson, a man devoted to his God and his great mission as geographer of the west. Thompson arrived in the vicinity of Calgary 23 days out from Cumberland House, in the fall of 1786. "In the following October, six men and myself were fitted out with a small assortment of goods to find the Peeagon Indians and winter with them in order to induce them to hunt for furs and make dried provisions; to get as many as possible to come to the houses to trade and to trade the furs of those who would not come".

As he approached the Bow, he travelled ". . . for three and twenty days . . . . . over fine grounds looking for the Indians without seeing any other animals than a chance bull bison. From the killing of a few, we produced our provisions . . .".

On the Bow, he wintered with Saukamappee, Boy Chief. Born a Cree to become a Blackfoot chief, Saukamappee had defected from his native tribe under pressure of family trouble. This defection and his subsequent seniority among his enemies was a rather forthright resolution of troubles of a kind that have since beset many residents of the Bow Valley. Thompson's accounts of his discussions with Saukamappee as related in his "Narratives" are the earliest of the Blackfoot and their customs, and to this day remain a classic on the subject.

Game was scarce in 1786-87, and so were the plains tribes. Smallpox had beset them. Thompson avowed that since the people who relied on it were gone, Providence had also removed the game, no longer needed among these decimated people.

With respect to other natives, Thompson remarked on the "Stone Indians"[1] ". . . in strict alliance with the Nahathaways (Cree), and their hunting grounds are on the left bank of the Saskatchewan and eastward and southward to the upper part of the Red Deer, and their number 400 tents each containing about 8 souls . . .". They sometimes cooked their food in boiling water heated by hot stones. The name may have a derivation not associated with the Rocky Mountains.

The Sussees (the Bad Ones), Beaver in origin, number ". . . ninety tents, some 650 souls . . .". These people from the Peace River country had migrated to the Bow Valley as the result of a quarrel over a dog.

Old Saukamappee and the Sarcees demonstrated a factor in migration which is still sending people to the friendly western plains.

A century and a half ago, the upper Bow River Valley was the stronghold of the Stonies. Adjacent to them on the north and east were the Sarcees, who formed a loose fourth member of the Blackfoot Confederacy. This confederacy composed of Blackfoot (Siksikaw), Blood (or Kainai), and Peigan (or Pikuni, the Poor Robes) Indians, was the most powerful on the western plains of Canada, and probably second to none on the continent, being better organized and more belligerent, although less numerous, than the Sioux. They were ". . . against every man and every man's hand against them".

Three linguistic stocks were present: the Algonquian Blackfoot; the Siouxian Stonies; and the Athapascan Sarcees. These people followed the great brown herds, attended their great annual festival (the Sundance), made war upon one another, and then relaxed at huge parties or dances made by one or another of their numerous societies. Among the Blackfeet, the societies included the Horns, the Old Wives, the Crazy Dogs, the Prairie Chickens, the Crows,

[1] "Stonies" – Assinaboines, a branch of the Sioux recently removed (in Thompson's time) to this country as the result of a smallpox epidemic – thus " Rocky Mountain Assinaboines" and hence, "Stonies".

and many others. A prominent and successful man might pass through several of these in his lifetime. It was a good life with the excitement of war and the dances, the discipline of the camp, and the competition of the hunt. For the sporting gentry, there was a game of hand or tossing the stick, and many a fine horse changed ownership in these sessions.

Henday, Thompson, and others found it to their liking. No doubt numerous nameless whites adopted the way of life permanently. Natives such as Thompson's old friend, and others, changed allegiance; women were stolen in raids. We hear people remark on what a melting pot Calgary has become in the last few years – the last few centuries would be more accurate.

Thompson departed the scene in the spring of 1787, to return briefly in the fall of 1800 during an exploration trip out from Rocky Mountain House. He noted the latitude of his Bow River crossing, remarking that it was in the vicinity of his wintering grounds of several years earlier, thus establishing the locality of the former camp. He proceeded south to the Highwood River, and thence westward to ". . . the Gap at the foot of the Rocky Mountains . . .", and back to Rocky Mountain House.

In 1832 the first walls in the land were raised at Bow Fort on the right bank of Bow Fort Creek (near the Hector boys' camp), just above its confluence with the Bow. This establishment, an outpost of the Hudson's Bay Company, was shortlived. Empire trade was not worth the candle in the Blackfoot confederacy. Several men died demonstrating that there is no profit in trading powder and ball for coarse fur (the Blackfoot did not trap but traded only buffalo and wolf robes), only to receive the ball back again in exchange for their own hair. The fort was abandoned, and burned by the Indians within about two years. Traces of it are still visible.

The American Fur Company built a fort on the site of the present city of Calgary in 1833. By that time, all the young warriors in the vicinity wanted blond scalps for the forelocks of their war ponies (a forerunner of the coyote tails waving from the aerials of hot rods), and several more young adventurers far from home lost their hair under the Blackfoot knife. The fort was abandoned and, of course, burned.

Peter Fiddler in his wanderings passed by Calgary in 1792, attempting unsuccessfully to entice the Blackfoot to make the long trip to Hudson's Bay to trade for things they had never heard of, didn't need, and didn't want – then.

During the middle part of the last century, travelling men came and went. James Sinclair was reported to have travelled through the Kananaskis[1] Pass in 1848. Simpson went over the Vermillion Pass at least once on his astonishing transcontinental journeys. Other unknown persons came and went, some passing safely, others providing sport for young warriors of the plains out to test their metal.

The most important of these travelling men and explorers were Palliser and his group, for Palliser had with him a geologist named Hector, and what can a country ever amount to without a geologist?

Palliser's party approached from the northeast in July, 1858. The party stopped to "make meat" at Lat. 51° 21′, Long. 113° 50′, a place designated as "Slaughter Camp", where they replenished their larder by the sum of 17 fat buffalo cows. When this meat was dried, they moved on to headquarters at the site of Bow Fort. From "Slaughter Camp" Palliser made a journey to the 49th parallel. In the meantime Hector had moved on to the site of old Bow Fort. His men, largely Cree breeds, were near panic at the thought of their proximity to the Blackfoot.

On August 18th Palliser started across the mountains via the Kananaskis Pass to the Elk River. He returned via Kootenai Pass and crossed the Bow River, northbound for Rocky

[1] "Kananaskis" was a Stony Indian who had survived a wondrous blow by a war axe in the hands of some unfriendly person, and so became sufficiently famous to earn this geographical niche in posterity.

Mountain House, at Lat. 50° 55′, on September 14, 1858.

In the meantime, Hector was carrying on with his geological surveys according to his instructions. In these days when geologists are so much in demand – they sometimes must be wooed with cars, expense accounts and comfortable assignments – it is refreshing to consider Hector's outfit for a trip across the mountains and return to Fort Edmonton.

Having separated from Palliser at "Slaughter Camp" he proceeded to Bow Fort, where he again halted to make more meat and to trade with the Stonies for other articles. It was there that Palliser found him on his return from his trip to the 49th Parallel, and it was from there that he departed in mid-August with the Stonies, Peter Erasmus and one "Nimrod", as Hector dubbed him, and two Cree breeds, making 5 in all, with 8 horses. Hector carried for his personal comfort a little tea and "grease".

He noted indurated shale beds in the Gap which are different than the dark shales downstream – probably Banff and Colorado marine strata respectively – as he noted that the downstream shales overlie "grits" – Blairmore?

His first view of the Bow Valley beyond the front range impressed him as follows: "The Peaks on either hand were of bold, grotesque shapes, caused by the varying resistance which the contorted strata composing the mountains present to the atmosphere. They are formed of thick bedded limestones with fragments of encrinite stems, sometimes blue and crystalline, at others, dark, earthy and bitumous. Alternating with these are groups of earthy shales which are only preserved high up in the mountains so that I had not an opportunity of examining".

Since Hector's observations are of particular interest in this volume, we shall take the liberty of indulging in a few more quotations from his Journal. On August 12th, he and Bourgeau (the botanist of the expedition) climbed Grotto Mountain ". . . returning for breakfast . . .", and moved camp that afternoon to the meadows below the Three Sisters, where he noted the gap in the Rundle Range behind Canmore. He also noted that "to the southeast, this valley seemed to be continued by a depression in the mountains caused by the absence of hard beds to protect the strata of soft shales which here form a beautiful syncline". On August 16th he climbed Cascade Mountain and made a correlation of strata found there with those previously observed on Grotto Mountain on the basis of an 80 foot, barren, buff weathering bed overlaid by a cherty *Productus* bearing limestone.

Later, on August 17th, while viewing the Bow Falls, he shot two ewes, the meat of which made the whole party ill and so, suffering from colic, they crossed the Vermillion Pass (and away from our area) for the field season of 1858.

Nimrod defected at this time, and a few days later fell in with the Earl of Southesk's hunting party. The two groups had passed within a few miles of one another, neither having any knowledge of the other's presence. What a meeting that would have been in this great lonely land!

In the summer of 1859 Hector was in Cypress Hills, whence he departed on August the third. After no little trouble with the Blackfeet, he saw again the chimneys of old Bow Fort. Strewn about was the wreckage of several carts destroyed by some American adventurers who, having departed the day before across the mountains, had no further need for them.

Camped once again on the meadows near Grotto mountain, Hector committed to his Journal the following encouraging pronouncement, – "There would not be the slightest difficulty with time and provisions in working out completely the structure of this portion of the Rocky Mountains and perhaps, from the clear manner in which the enormous faults and foldings of the strata are displayed, obtaining most valuable inductions for application to the general principles of geological science. We have indeed in these mountains, a perfect desertion of the complicated disturbances,

the nature of which in other regions the practical geologist has to grasp and picture in his mind from detached and superficial observations".

This trip his Journal notes Minnewanka ("Big Lake"), and "the warm mineral springs . . .". Rocky Mountain Tours now include both these and other wonders in an afternoon tour. Hector left the valley via Pipestone and Howse Pass en route to Rocky Mountain House.

Among the travelling men have been geographers, merchants, adventurers and scientists. Next came two men of God, George McDougall and his son the Reverend John McDougall, and their families in the early 1860's. They established the settlement of Morleyville in 1864, and were a great influence among the Stonies, who adopted Christianity long before the other tribes. Under the McDougall influence, they avoided the whiskey forts of southern Alberta, trading soberly and advantageously at Fort Edmonton, camping far from temptation (Stony Plain) and going in daily to barter. They are still aloof and do not mix readily with the whites as do the more gregarious Blackfeet. George McDougall died while hunting buffalo, in a blizzard, somewhere near the site of the Highwood Development in north Calgary. His body was recovered and now lies beneath the grassy slope overlooking the old church built by the family at Morley.

It was due to the influence of the McDougalls that there was no "Wild West" in the foothills part of the Bow Valley. The Stonies were a close-knit, tractable group, removed from the influence of the whiskey traders.

Times were changing. A wanderer, Sam Livingstone, built a cabin at the confluence of the Elbow and the Bow. Downstream at Blackfoot Crossing, Lafayette French built a cabin for the purpose of trading to the Blackfoot. Fred Kanouse forted up near the present site of the Golf and Country Club in 1871, and invited trade from both Kootenai and Bloods, – deady enemies. That was retailing the hard way. In 1872, the Royal Northwest Mounted Police arrived and were welcomed by Sam Livingstone, who decamped in their favour to a point southwest of Calgary. A fort was built and the Officer Commanding, Brisebois, promptly named it for himself. Fort Brisebois it was until the first dispatches under that heading reached Ottawa, and then Calgary was born. To the Blackfoot, it is still Mowkinits, the Elbow. The brash young Brisebois also announced that he had found the ruins of Fort Jonquiere – most likely the ruins of the American Fur Company's establishment.

Houses and forts sprang up everywhere. Where were the Blackfeet who had driven away the rugged furtraders in earlier days? Decimated by smallpox, debauched by alcohol, and semi-starved by slaughter of their herds, they huddled in their lodges, dazed by their calamity. Occasional forays against wagon trains and isolated buildings continued. However, a naked, half-starved man, recently recovered from smallpox and armed with a flintlock, is no match for a well fed adversary behind a wagon box and armed with a repeating rifle. So ended the glory of the Blackfoot Confederacy.

In 1877, Treaty No. 7 was signed at Blackfoot Crossing. Signatory were the Blackfoot nation, the Sarcees and the Stonies. Thus the plains tribes relinquished their heritage.

The infant Calgary grew rapidly, mindful of the belligerent Blackfoot nearby, particularly during the Riel war when there were a few scares.

The coming of the railroad coincided with the disappearance of the buffalo. The "Wild West" was gone. There were sharp memories, however. The yells and crashing pistol shots of roistering cowpunchers were not unlike the warcries and thundering hoof beats of the ponies of the young Blackfoot warriors as they raced across the river bottoms to cut down some unfortunate straggler from the old American fort. The effectiveness of these attacks was recalled still more vividly when Crowfoot, the great Blackfoot head chief, angered by white arrogance, threatened to allow his warriors to blacken their faces against the whites.

A coach road was built so that people might have easy access to the ". . . warm mineral springs . . ." noted by Hector. The railroad replaced the old coach road, the city grew, the prefix "Fort" was dropped. Stephen Avenue became Eighth Avenue and men no longer went about armed.

The great herds of cattle replaced the big brown grasseaters of the original owners of the country, and finally plows turned the grass 'wrong side up" and even the open range was gone.

Through it all the Stonies remained aloof, living in their foothill and mountain fastnesses much as they had always done, the old Chief Bearspaw keeping them together, apart from all others. Denied free admittance to the Calgary Stampede in 1949, they stayed away to a papoose, and further, made a rain dance that will go down in history – it rained all Stampede week.

There is a highway and a railroad through the Stony Reserve. Plans for the new trans-Canada highway call for a straight road along the valley, close to and parallel to the old route. Officials of the Department of Highways met with Stony chiefs two years ago to negotiate the right of way. The chiefs listened long and politely to the representatives of the Queen. Their turn to speak finally came. A young chief rose. He said: "You now have a good highway through our reserve and wish to build another one about half a mile away and running the same direction. We think the white man needs some new engineers!"

Some say that the Rocky Mountain Assinaboines will never change.

FIGURE 1

A part of Thompson's map. River names in the vicinity of Lat. 51° N., Long. 114° W., are in the Blackfoot tongue. A translation is as follows:

Kapik-ske	Poplar Creek (could be Soreface Creek).
Ho-Kaik-ske	The creek where the trees are — the Blackfoot once had a trail up this stream; possibly our Sheep River.
Ttoukai-you	Curving Creek; the present Tongue Flag Creek.
Spitchee	Highwood River or High River.
Stamuk ske piskun	Bull Pen.

COPY OF A PORTION OF

MAP

— OF THE —

NORTH-WEST TERRITORY

— OF THE —

PROVINCE OF CANADA

From actual Survey during

the years 1792 to 1812

This Map made for the North West Company in 1813 and 1814 and delivered to The Honorable William McGillivray then agent, Embraces the Region lying between 45 and 60 degrees North Latitude and 84 and 124 degrees West Longitude comprising the Surveys and Discoveries of 20 years namely the Discovery and Survey of the Oregon Territory to the Pacific Ocean, the Survey of the Athabasca Lake Slave River and Lake from which flows Mackenzie's River to the Arctic Sea by Mr. Philip Turner, the Route of Sir Alexander Mackenzie in 1792 down part of Fraser's River together with the Survey of this River to the Pacific Ocean by the late John Stuart of the North West Company,

by David Thompson
Astronomer & Surveyor

(Sgd) David Thompson.

ATHABASCA RIVER

SLAVE LAKE

GREAT SLAVE LAKE

GREAT BEAR LAKE

PEACE RIVER

ELK OR ATHABASCA RIVER

SHEEWAP RIVER

COMMEAWAMAN RIVER

THOMPSON'S RIVER

FRASER'S RIVER

COLUMBIA RIVER

NELSON'S MOUNTAINS

McGILLIVRAY'S MOUNTAINS

BOW RIVER

PACIFIC OCEAN

55 54 53 52 51 50 49 48

124 123 122 121 120 119 118 117 116 115 114 113 112 111 110 109 108

THE BOW DRAINAGE BASIN: POWER, WATER, AND SOME GEOLOGY

BY KARL A. MYGDAL[1]

The Bow drainage basin supplies essentially all the hydro-electric power in Alberta, and its developer, Calgary Power Ltd., is the principal producer of power in the province. Its main transmission system of some 4,100 miles length, serves an area extending from 130 miles north of Edmonton to the United States border, and from Banff to Saskatchewan, and has inter-connections with all other major systems in the province. The Bow was the first of the Rocky Mountain streams to be investigated for its power possibilities by the Department of the Interior, Water Power Branch, which began its work in 1911 and published its results in 1914 in the singularly interesting Water Resources Paper No. 2 "Bow River Power and Storage Investigations" by M. C. Hendry. The introduction to this work states:

"The Bow River is a typical mountain river. West of Calgary it drains an area of 3,138 square miles of which that part above the Kananaskis Falls, 1,710 square miles in extent, may be considered to lie wholly in the Rocky Mountains. It has a very steep slope and in several places falls occur. The head waters of the river lie at an elevation of about 6,500 feet above sea level. The flow of the river is typical of all mountain streams, subject to sudden variation and greatly influenced by conditions of temperature. During the winter months the flow is much reduced but in the hot summer months of June and July the floods occur and the variation between high and low water is very great. It has been computed from levels taken by the Canadian Pacific Railway Company at Bow Bridge and Kananaskis Bridge that at Kananaskis Falls, jsut below the mouth of Kananaskis River, a flood of 45,000 C.F.S. has occurred. A low water discharge of 550 C.F.S. has been recorded at the same point".

The mountains capture the moisture from the Pacific winds, accumulating it in vast snow and ice fields along the Continental Divide, and provide the high topographic gradients down which the melt-water can exert its foot-pounds of energy. In the Bow Valley the mountains lie closer to large markets for power than in any other place along the Alberta Rocky Mountain front. It was natural that the earliest power developments should begin here. Future development of the additional available plant sites is inevitable.

The route of the 1956 field trip from Cochrane to Canmore passes the two largest hydro-electric plants in the system and in the Province of Alberta. The river is visible from the highway at many points. Beautiful as is its majestic valley, its usually clear waters, and its rushing riffles, this stream means more than lovely scenery and an eroding agent which has conveniently exposed the outcrops which we shall see today. It means abundant electric power for homes, industries, farms and offices. Figure I shows the location of the present and future plants, the drainage basin, the principal streams and the mountain ranges. Table I lists the capacities of the plants and storage reservoirs.

THE DRAINAGE BASIN

Only that portion of the Bow system lying above Calgary is now developed for power. The developed basin is bounded by the Continental Divide on the west, by the watershed between the Bow and the Saskatchewan rivers to the north, and by the watershed between the Kananaskis and Elbow rivers on the southeast.

THE MAIN STREAM PLANTS

Approximately half of the total power is developed in the main channel of the Bow River itself, in four plants, named in ascending order from Calgary: Bearspaw (22,000 h.p.), Ghost

[1] The Pure Oil Company, Calgary. The friendly assistance of Mr. W. E. Ross, Director of Public Relations of Calgary Power Ltd., in providing data, pictures, and the pamphlets on the Spray Project (see the map envelope) is gratefully acknowledged.

(67,450 h.p.), Horseshoe (20,000 h.p.), and Kananaskis (24,000 h.p.). Of these only the Ghost is visible from the highway; its reservoir, seven miles long, extends from the mouth of the Ghost River, spanned by the highway bridge, to Morley. The plant is of conventional type. Its dam is built on an outcrop of Belly River sandstone exposed as a thrust sheet of the disturbed foothills belt, dipping steeply westward. Excellent exposures exist in the spillway channel below the dam. Ghost is the only Bow River plant with storage. The other three are "run-of-the-stream" plants.

The Bearspaw plant, the lowest on the river and the first above Calgary, also is the youngest. It was completed in 1955, and is the only one east of the foothills belt. Maximum height, in the river, is 64 feet. The dam is 900 feet long, 20 feet wide at the top, and 350 feet wide at the base. A core of impervious rolled clay is covered by a heavy blanket of gravel. It is interesting to note that both the concrete section, which includes the power house, and the clay portion are built on bed rock which has been scrubbed with water and wire brushes. The bed rock is flat lying beds of Paskapoo sandstone. The dam is built in a narrowing of the valley bordered by bluffs 150 feet high, approximately four miles west of Bowness, a western suburb of Calgary. A feature of the 22,000 horsepower turbine is that the pitch of the blades varies automatically, depending on the head of water and the amount of load the generator is called upon to deliver.

Above the Ghost plant, mentioned earlier, is the Horseshoe plant, two miles below the junction of the Kananaskis and Bow rivers. It is the earliest large plant built by Calgary Power Ltd., and was completed in 1911, with a capacity of 20,000 horsepower. Horseshoe Falls, caused by outcrop of very hard Cardium sandstone, provided an excellent site, with a natural head of 50 feet, which was raised to 72 feet by a dam.

A similar situation was found two miles upstream, where the Bow passes across another thrust sheet of Cardium sandstone at Kananaskis Falls, just below the mouth of the Kananaskis River. It was natural to follow the Horseshoe plant with one at Kananaskis Falls, and the Kananaskis plant was completed in 1913 with an initial capacity of 12,000 horsepower, enlarged to 24,000 in 1949. This plant is easily visited by turning south to Seebe at the forestry road.

THE TRIBUTARY STREAMS PLANTS

The remaining plants of the system are found on the mountain rivers tributary to the Bow: the Kananaskis, the Spray and the Cascade. They are a different breed from the main stream plants. The latter are in a plains region and are built in a broad valley on Cretaceous or Tertiary rocks, utilizing modest river gradients, low heads, and large water volumes. Only one has any storage. The mountain plants are more spectacular. Located in deep valleys carved in or through hard Palaeozic carbonates, they have high head, but relatively low volume, getting their foot-pounds of energy from the feet of drop rather than from the volume of water. Substantial storage reservoirs are found on each of these rivers.

The Bow River is a large stream before it reaches Banff, where the first power-developed tributary joins it. It has been joined by the brawling creeks flowing off the great peaks along the Continental Divide, stretching from Mount Thompson and the other 10,000 footers above Bow and Hector Lakes, southeastward to Citadel, Fatigue and Nasswald peaks bordering Mount Assiniboine Provincial Park (B.C.). From the east, from mountains hardly less spectacular, come the waters from the Sawback Range, the Slate Mountains and the Eisenhower group, through Pipestone River, Corral, Baker, Johnston and Forty-Mile creeks. When the Bow River plunges over Bow Falls it is a river indeed. In contrast, the tributary streams are small. However, the rugged topographic environment provides water storage opportunities and steep gradients so that modest volumes of water can be utilized to advantage.

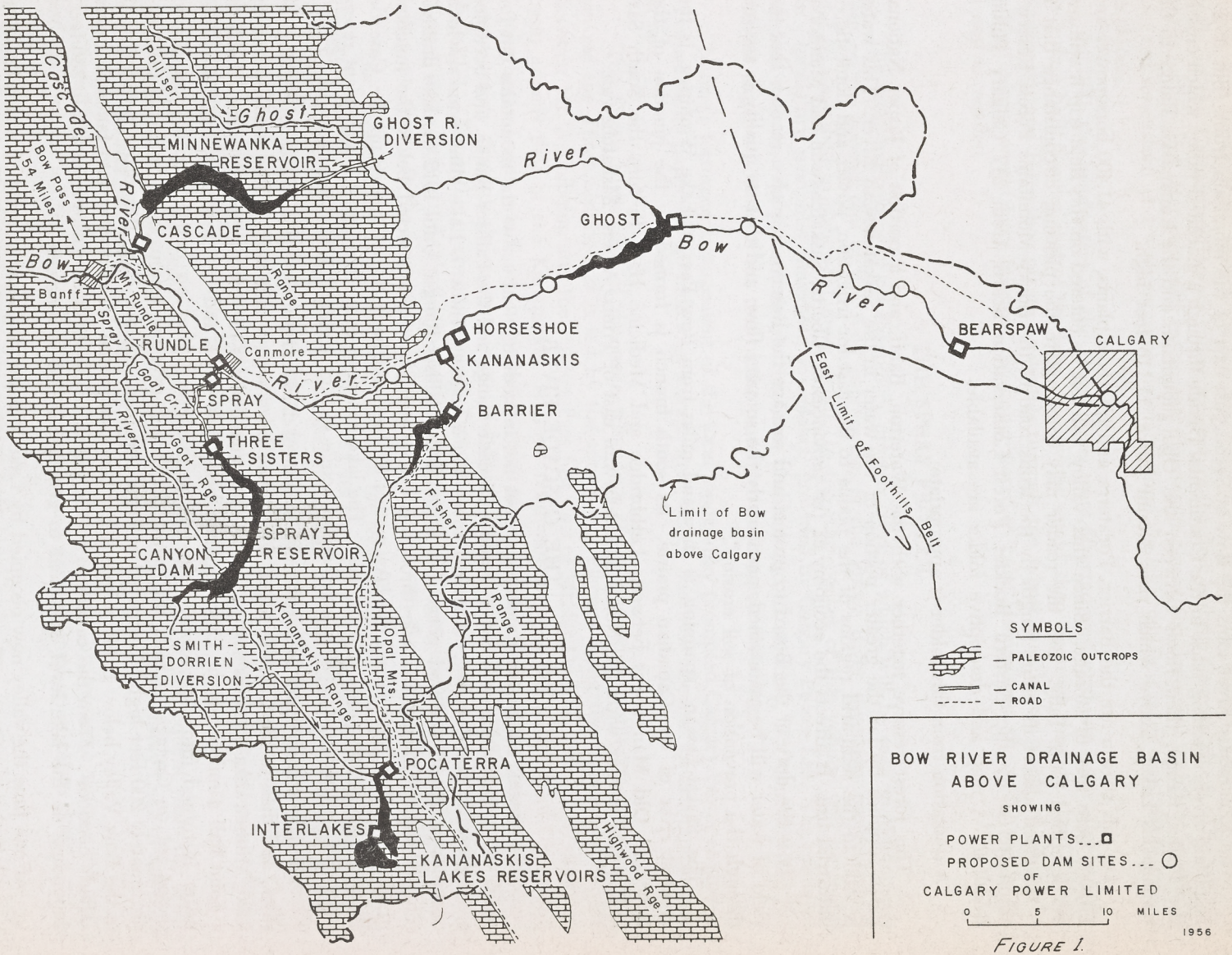

Cascade River
Bow Pass 54 Miles
Pallister
Ghost
GHOST R. DIVERSION
MINNEWANKA RESERVOIR
River
CASCADE
Bow
Banff
Mt. Rundle
Spray River
Range
TRUNDLE
Canmore
River
SPRAY
Goat Cr.
Goat Rge.
THREE SISTERS
SPRAY RESERVOIR
CANYON DAM
SMITH-DORRIEN DIVERSION
Kananaskis Range
Opal Mts.
Fisher Range
POCATERRA
INTERLAKES
KANANASKIS LAKES RESERVOIRS
Highwood Rge
GHOST
Bow
River
HORSESHOE
KANANASKIS
BARRIER
Limit of Bow drainage basin above Calgary
BEARSPAW
CALGARY
East Limit of Foothills Belt
SYMBOLS
PALEOZOIC OUTCROPS
CANAL
ROAD
BOW RIVER DRAINAGE BASIN
ABOVE CALGARY
SHOWING
POWER PLANTS
PROPOSED DAM SITES
OF
CALGARY POWER LIMITED
0 5 10 MILES
1956

FIGURE 1.

THE KANANASKIS RIVER

The Kananaskis River joins the Bow at Seebe, just east of the mountain front. But it is a mountain river, reaching back to the Continental Divide through a glaciated valley which crosses the Fisher Range, then flows between the Opal mountains and the Kananaskis Range to the Kananaskis Lakes, above which rises Mount Joffre, 11,116 feet high.

On this stream are the Barrier, Pocaterra and Interlake plants, with 41,400 horsepower and 170,000 acre feet of storage. Since this valley will not be entered on this field trip it will not be described more fully. But the reader may contemplate the pleasing circumstance that it is traversed almost its entire length by the trunk road of the Rocky Mountains Forest Reserve, administered by the Eastern Rockies Forest Conservation Board, from 517 Calgary Public Building. A map and descriptive folder are available.

A quotation from this folder is appropriate:

"This forest reserve together with the Waterton, Banff, and a portion of Jasper National Parks supplies by far the greater portion of the water in the Saskatchewan River. This water is vital to the semi-arid regions of the plains to the east for irrigation, power and domestic or industrial use. It affects the economy of the provinces of Alberta, Saskatchewan and Manitoba.

"It is the duty of the Board to protect and manage the Reserve in such a manner that the yield of water will be maintained, particularly the summer flow, and that its quality is assured through the prevention of soil erosion".

The Saskatchewan, spanning a thousand miles from Bow Pass to Lake Winnipeg, is the greatest river of the Canadian prairie. Its south branch is formed by the junction of the Bow and Old Man rivers between Lethbridge and Medicine Hat. In turn the South Saskatchewan merges with the North Saskatchewan east of Prince Albert, Saskatchewan.

THE CASCADE RIVER

This stream, unlike the Kananaskis, does not immediately cut across the mountains but for much of its course flows between Rundle-Cascade Range and the Palliser Range, and occupies a Cretaceous-floored valley. Attached to it, like a huge appendix, is Lake Minnewanka, which occupies a glacial-modified gorge cut through the Palliser Range. Until 1912 the lake drained into the south flowing Cascade through Devil's Creek, but dams erected below the junction in 1912 and 1942 have raised the lake waters 81 feet and have backed water up the Cascade River so that it now flows into the lake. The lake has been converted into a magnificent reservoir with a capacity of 100,000 acre feet of active storage through a working range of 35 feet.

The lake-stored water is led through a control dam and pump station to a canal and a penstock, and then to the Cascade plant, which may been seen ¼ mile west of the road leading to Lake Minnewanka 4½ miles east of Banff. The canal follows the contour along a gentle knoll to a point half a mile from the Cascade River bed (now dry) and 350 feet above it. Here the water is turned into a penstock eight feet in diameter. After an initial descent over gentle slopes cut on Cretaceous beds this penstock plunges over precipitous cliffs of glacial drift approximately 200 feet high. Composed of hard cemented boulder clay, this drift is widespread in the Bow Valley below Banff, where it has been sculptured by rainwater into fantastic forms called "hoodoos". From the canal-end to the power house the head varies from 315 to 330 feet, depending on the lake level, sufficient to generate 23,000 horsepower.

At one time the valley now occupied by Lake Minnewanka was the route by which the Bow River left the mountains. The river was diverted down its present course by the headward erosion of a stream occupying the present Bow Valley to the southeast and emerging from the mountains through the Exshaw gap. Probably as a result of tectonic movements occur-

ring long before the glacial period, the Exshaw gap was lowered relative to the Minnewanka valley, and the Exshaw stream (which MacKay, p. 17, calls the Spray) easily lowered its grade in the Cretaceous-floored valley to capture the Bow and the Cascade rivers. The Minnewanka valley was later occupied by an east flowing glacier which deepened it and, on receding, plugged its eastern end with moraine debris to form the lake, which is more than 300 feet deep in places.

In 1941 the headwaters of the Ghost River were diverted westward into Lake Minnewanka by a dam built 5 miles east of the lake. This water could then be used through the Cascade, Kananaskis and Horseshoe plants, as well as through the Ghost and lower plants to which its natural course would have taken it. By being stored in Lake Minnewanka the water can be released as needed.

THE SPRAY PROJECT

The most interesting of all the power projects, part of which will be seen in Whiteman's Gap on the second day of the field conference, is the Spray River diversion project which will be described in somewhat more detail. In the map pocket of this volume will be found an explanatory pamphlet illustrated in colours, provided by Calgary Power Ltd. The principal diagram and the text present clearly the basic problem and its solution. For continuity in the present paper a portion of the text of the pamphlet is repeated following:

"Nature's fortunate arrangement of the local topography prompted Calgary Power engineers to conceive on paper the 20 mile long storage area which has now become an accomplishment in fact.

"The Spray River, one of the main tributaries of the Bow, rises in the area south of and beyond the Three Sisters, and is fed by the snows and glaciers along the Continental Divide between Mt. Assiniboine and the Palliser Pass just west of Mt. Sir Douglas. The Spray drainage basin adjoins that of the Kananaskis. It flows northward to meet the waters from Upper and Lower Spray Lakes, which are immediately south of the familiar Three Sisters Mountain, thence northwesterly through the Spray canyon and Spray Valley until it finally joins the Bow River at Banff". (Note: the present man-made Spray Lake is shown on the Banff Park topographic sheet, Third edition 1955, 3 miles to one inch, while the now submerged Upper and Lower Spray Lakes are shown in the map issued by the National Park with the park entry permits).

"The scheme of the development was to divert the water of Spray River from its natural course at Spray canyon and lead it, while maintaining its elevation, to a point above the Bow River where the vertical drop could be concentrated in a short horizontal distance. Water dropping through that height could produce large quantities of electrical power. This was done by damming the Spray canyon, diverting the water through Spray Lakes valley into Goat Creek valley which runs parallel to the Bow River valley, and finally bringing it out over Whiteman's Pass to rejoin the Bow River at Canmore".

"Calgary Power first became interested in Spray in 1921, and in subsequent years the great power potentialities were recognized because of the proximity of Upper Spray Lake to the Bow Valley and the fact that it was 1,120 feet above it.

"Investigations carried on through the years were climaxed by intensive surveys of 1947 and 1948 which led to the application for license and governmental approval in 1948".

MAIN DAM

"Near the south end of the project, the main dam blocks the flow of Spray River down the Spray canyon, its earth-fill bulk rising 198 feet from the lowest level of bed rock to crest".

STORAGE RESERVOIR

"The main dam, by raising the water 165 feet, created a reservoir in the Spray Lakes valley which covered 4,800 acres of land. All except 400 acres, which were contained in Upper and Lower Spray lakes, had to be cleared of timber and brush before flooding could take place. This clearing represented a major part of the project".

The Spray reservoir has a capacity of 190,000 acre-feet of active storage. The water will not only be used in the Spray plants, but will be used to supplement winter flows at existing and future plants on the Bow River below Canmore.

THREE SISTERS PLANT

"In order to contain the water in the reservoir, a dam was constructed in Goat valley immediately behind the Three Sisters mountain. This Three Sisters dam is 1,980 feet long and 48 feet high. Below the dam is located the Three Sisters power plant (3,600 h.p.) which will control the flow of water from Spray reservoir".

CANAL SYSTEM

"The water from Three Sisters plant is carried by a system of level canals and dykes down Goat valley and through Whiteman's Pass to the intake of the pressure tunnel high on the slopes of Chinaman's Peak above Canmore".

PRESSURE TUNNEL

"This tunnel, nearly 2,200 feet long, drops the water 905 feet from the crest of Whiteman's Gap to the Spray power plant at the foot of Chinaman's Peak. The top 1,236 feet of this tunnel is on a 45° slope with the lower 915 feet leading horizontally to the power plant. The excavated diameter of the tunnel was made 10 feet 6 inches. It has been finished to seven feet six inch diameter by concreting at the upper end and steel lining the lower end for 500 feet".

SPRAY PLANT

"Nestled in a niche blasted in the hard rock wall at the base of Chinaman's Peak, Spray plant is solidly placed to withstand the force of water dropping over 900 feet to its turbine. It is the main power plant of the Spray development, producing 62,000 h.p., more than any other single plant in the Calgary Power system".

RUNDLE PLANT

"The water from Spray plant is carried by a canal to a point close to the Bow River west of Canmore, where it takes its final plunge of 325 feet through a steel penstock to the Rundle plant, and finally discharges into the Bow River", generating 23,000 h.p.

THE GLACIATED TOPOGRAPHY OF THE SPRAY PROJECT

The mountains of the Bow drainage basin had acquired approximately their present shape before the last glacial period. But the changes brought by the glaciers, while minor in comparison to the major dimensions of the mountains, were the controlling factor in making the Spray project possible.

As Camsell reports: (in Water Resources Paper No. 2)

"During the glacial period the eastern slope of the Rockies was drained by eastward moving valley glaciers which became confluent as piedmont glaciers on the plains. In the basin of Bow River all the valleys were occupied during the glacial period by valley glaciers moving slowly downgrade toward the east.

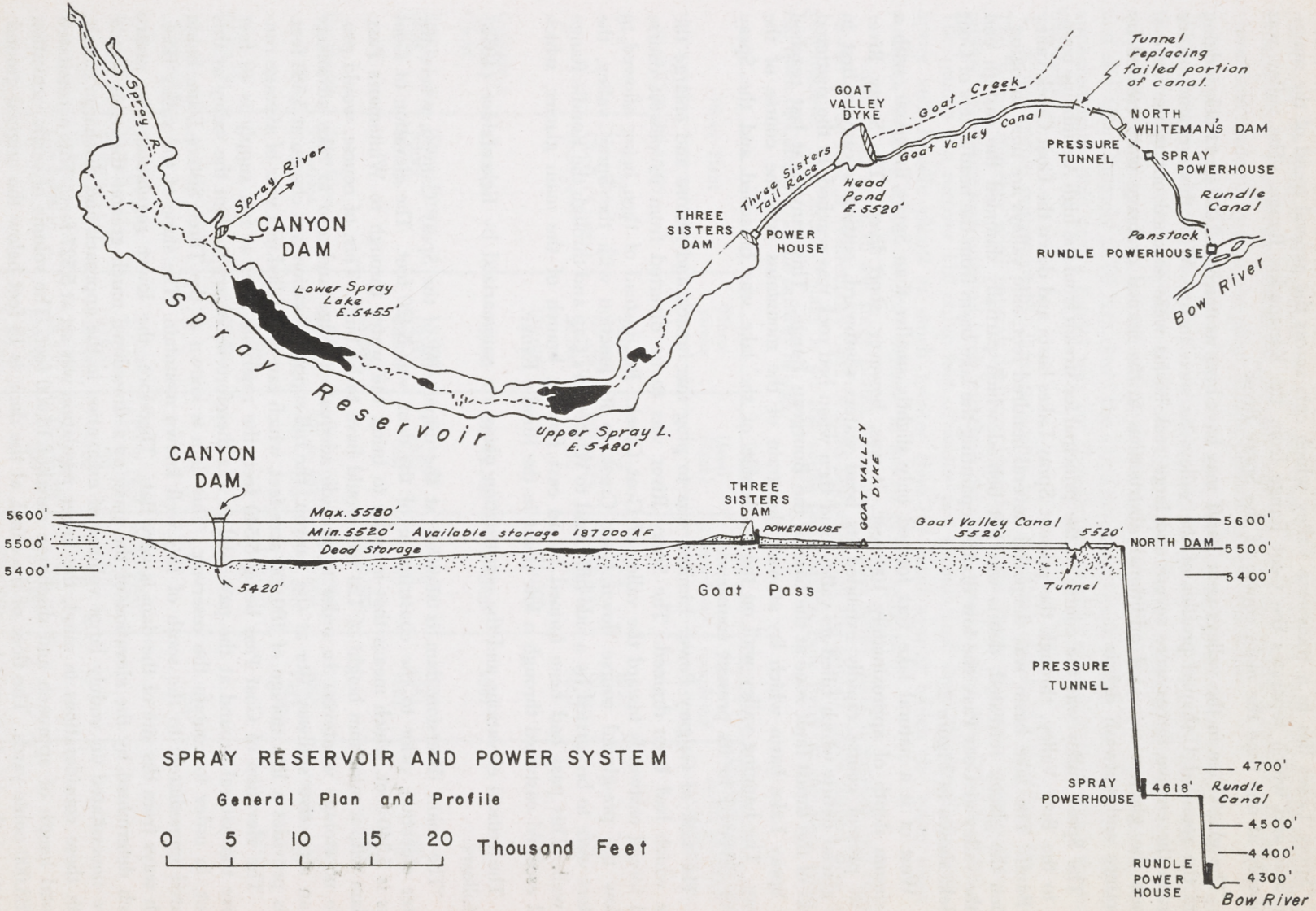

Spray R.
Spray River
CANYON DAM
Lower Spray Lake E.5455'
Spray Reservoir
Upper Spray L. E.5480'
THREE SISTERS DAM
POWER HOUSE
Three Sisters Tail Race
GOAT VALLEY DYKE
Head Pond E.5520'
Goat Creek
Goat Valley Canal
Tunnel replacing failed portion of canal.
NORTH WHITEMAN'S DAM
PRESSURE TUNNEL
SPRAY POWERHOUSE
Rundle Canal
Penstock
RUNDLE POWERHOUSE
Bow River
CANYON DAM
5600'
5500'
5400'
Max. 5580'
Min. 5520' Available storage 187000 AF
Dead Storage
5420'
THREE SISTERS DAM
POWERHOUSE
GOAT VALLEY DYKE
Goat Valley Canal 5520'
5520'
NORTH DAM
Goat Pass
Tunnel
PRESSURE TUNNEL
4700'
SPRAY POWERHOUSE
4618'
Rundle Canal
4500'
4400'
4300'
RUNDLE POWER HOUSE
Bow River
SPRAY RESERVOIR AND POWER SYSTEM
General Plan and Profile
0 5 10 15 20 Thousand Feet

FIGURE 2.

"Spray Lakes lies in a transverse valley which cuts across the general trend of the mountain axis and which separates the Goat Range from the Kananaskis Range. The valley was probably at one time the main course of the Spray River".

The glacial ice in the valleys near Banff may have been as much as 2,000 feet thick, judging from the rounded U-shaped profiles of the valleys as seen today. With this tremendous ice burden the erosive forces were severe and large rock basins were scooped out in the valleys. When the glaciers retreated additional obstructions to the normal drainage were created by moraines and outwash debris.

The Spray valley was the course of the principal ice stream from the high Assiniboine country to the Bow Valley, through the present Spray Lakes basin and down the Goat Creek valley to Banff. The lake basin was deepened several hundred feet; side valleys are now "hanging". When the glacier retreated, debris was left behind which partially dammed the eastern end of the valley at Goat Pass, the low divide separating the lake basin from the headwaters of Goat Creek, shown in Figure 2.

West of it a natural lake was formed only slightly smaller than Spray Reservoir, with a maximum depth of approximately 100 feet. It was, however, short lived. The Spray River in its present course rapidly extended its head waters southward, cutting a canyon first in the glacial debris which filled its valley, and then when bed rock was reached, in the shattered rocks of the thrust fault zone at the base of the Bourgeau Range. This canyon at last reached the Spray Lake basin which lay athwart the grain of the mountains and the course of the Spray. The hanging valley wall on the north side of the lake was breached and the Spray River diverted to its present course.

The task of Calgary Power Limited was to plug this breach and restore and enlarge the lake which had been drained. The Spray River was to be diverted from its newest course and forced eastwards toward the valley of Goat Creek. But instead of then being allowed to follow the pre-glacial course down Goat Creek to its junction with the Spray valley, the waters were to be carried by a side-hill canal to Whiteman's Gap and through the Rundle Range as well. This pass had been formed by an east flowing branch of the main glacier, which had escaped eastward through a low point in the Rundle Range.

The critical elevations and the construction plans are summarized by Eckenfelder (1952) as follows:

"The main diversion dam is situated at the upper end of the Spray Canyon, where the water elevation, prior to the construction of the dam, was 5,420 feet. The elevation of Goat Pass is 5,540 feet, which means that in order to bring the water through to Whiteman's Pass, a dam with a minimum height of 120 feet would have to be built. This, of course, would provide no storage whatever. In order to provide adequate storage and also to take advantage of an attractive spillway site at the canyon, the full supply elevation was chosen at 5,583 feet. This provides a live storage of 180,000 acre-feet, which can be refilled in a year of average run-off. The elevation of Goat Pass being 5,540 feet, the reservoir level at full supply is 40 feet above the natural ground at the pass, and it was therefore necessary to dam the valley at this point, in order to contain the reservoir. This dam is known as the Three Sisters Dam, being located immediately to the south of this well known mountain. The slope of the valley floor, both ways from the site of the dam is very flat. Therefore, the lower regulation was pretty much determined by the elevation of the pass, as a drawdown much greater than this would have necessitated an unduly large volume of excavation in the approach and discharge canals. With these considerations in mind, the lower regulation was set at 5,527 feet. This necessitated a total length of approach and discharge canal of 13,000 feet. The volume of earth excavation is 283,000 cubic yards. The floor of the canal, at the dam, is 18 feet below the original ground. In view of the head created by the dam, it was possible to install here a small power plant,

called the Three Sisters Plant, with a capacity of 3,600 horsepower. While the installation of this plant was not entirely economical, it was desirable as a means of controlling the flow to the canal system. This was available for use only with the reservoir above a certain elevation. Provision was made to by-pass the plant during periods of low reservoir".

A wide range of engineering problems was encountered and solved in this project. One of the most troublesome was the Goat valley canal, approximately 4 miles long, which brings the waters from Goat valley dike to Whiteman's Gap. During construction, a section of the canal 800 feet long, cut in the talus slope at the west portal to Whiteman's Gap, suddenly failed and slid approximately 2,000 feet down the slope into Goat Creek valley. Restoration of the slope appeared impossible and a tunnel was cut though the shoulder of rock against which the talus had rested.

Considerable unpreventable leakage occurs from the Goat valley dike and from the canal. This water, together with natural drainage from below the Spray system, is recovered by two pump installations and pumped back into the Goat valley canal against a total head of 300 feet. The pumps can recover 110 cubic feet of water per second and since the head through the Spray and Rundle plants is much greater than the head against which the water must be pumped, there is a large energy balance in favour of the operation.

Visitors can drive to the three plants. The road to the Spray plant is marked and clearly visible at the foot of Whiteman's Gap. A road leads through the gap to Three Sisters dam and powerhouse. The Rundle plant is on the south bank of the Bow River at the west edge of the town of Canmore, at the railway bridge.

TABLE 1

River	Plant	Horse-power	Head (feet)	Storage (acres-feet)	Year completed	Approximate kilowatt hours annually, (millions)
PRESENT PLANTS:						
Bow	Kananaskis	24,000	72	Nil	1913	115
	Horseshoe	20,000	72	Nil	1911	90
	Ghost (4 units)	67,450	110 to 75	75,000	1929	175
	Bearspaw	22,000	50	Nil	1954	80
		133,450		75,000		460
Cascade & diverted Ghost	Cascade	23,000	345 to 330	100,000	1942	55
Spray head waters	Three Sisters	3,600	65 to 25	210,000	1951	5
	Spray	62,000	900	Nil	1951	190
	Rundle	23,000	320	Nil	1951	65
		88,600		210,000		260
Kananaskis	Interlakes	6,900	127 to 73	100,000	1955	5
	Pocaterra	18,500	207 to 164	50,000	1955	55
	Barrier	16,000	155 to 120	20,000	1947	40
		41,400		170,000		100
TOTALS:		263,450		555,000		875
Possible Future Hydro Sites:						
Bow	Lac des Arcs	17,000	65 to 32.5	130,000		
	Russell	78,000	141 to 101	78,000		
	Radnor	33,000	60	Nil		
	Glenbow	48,000	100	Nil		
	Calgary	9,000	24.5	Nil		
	Chestermere	12,500	47.5 to 38	Nil		
	Shepard	120,000	300	51,000		
		317,500		259,000		

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THE ALBERTA GROUP OF THE BOW VALLEY AREA, ALBERTA

G. G. SCRUGGS[1]

INTRODUCTION

In the last fifteeen years considerable reconnaissance and detailed geological mapping have been done in Alberta's foothills and mountain belts. The Geological Survey of Canada and geologists of numerous oil companies have increased our knowledge of this region by issuing geological reports describing widely separated areas. The Alberta Group has been mapped throughout the length of Alberta's foothills belt. Numerous names for the group have been introduced into the literature since the first geological report was written by Hector in 1863. The names used in this report are those adopted by the Alberta Society of Petroleum Geologists as being most in keeping with precedence, custom, and uniformity.

The writer wishes to express his thanks to the management of Amerada Petroleum Corporation for granting permission to use the time necessary to write this paper, and to his co-workers for constructive criticism. Special thanks are extended to J. C. Scott, of Husky Oil & Refining Ltd., for the use of manuscript, maps, and charts of an unpublished report on the Alberta Group in the foothills. His report covers 450 miles from the International boundary in the south to latitude 55 degrees on the British Columbia -Alberta boundary in the north.

NOMENCLATURE

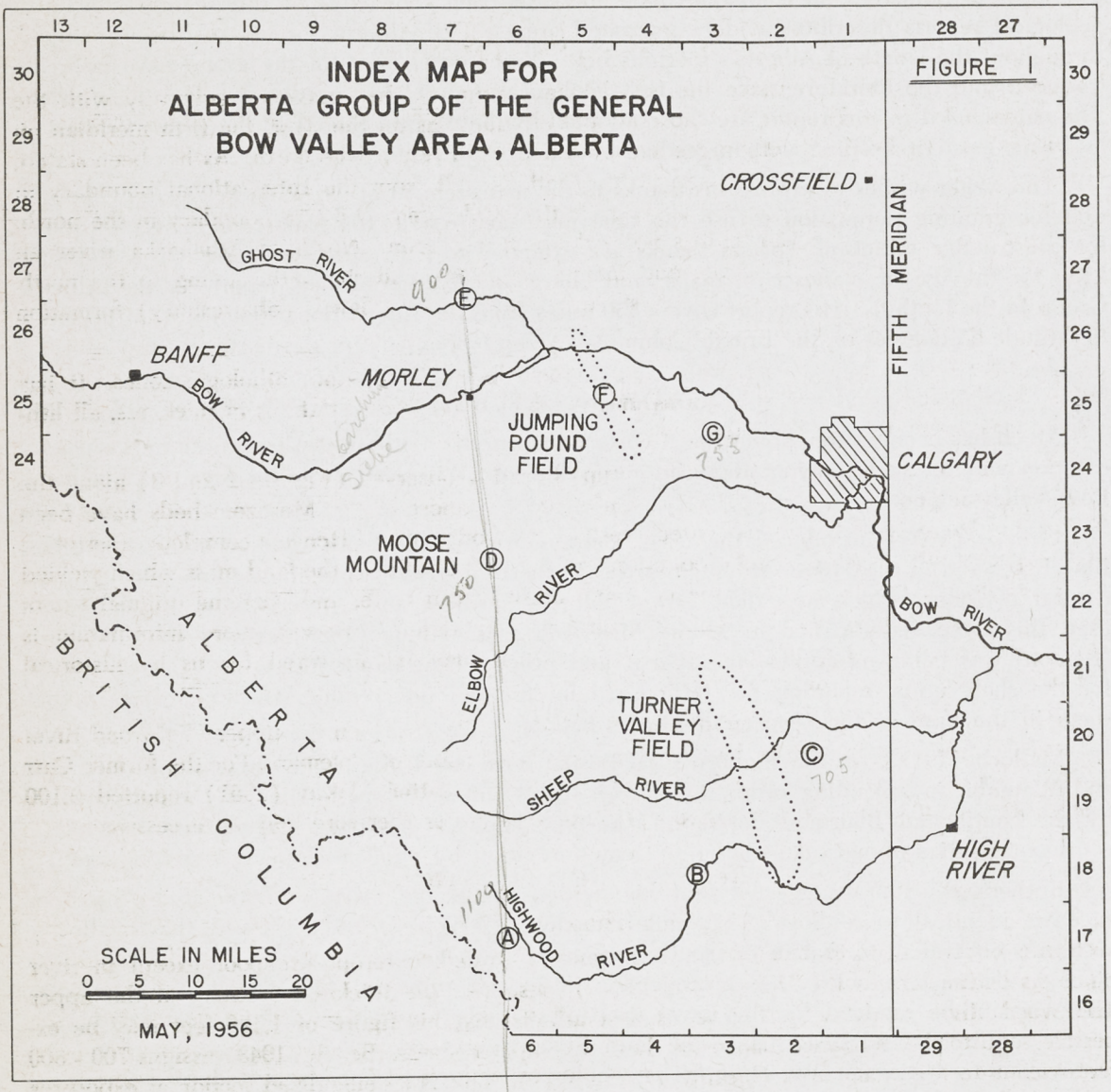
Much has been written about the Alberta Group in the foothills of Alberta, but in this paper, mention will be made only of those authors whose work is pertinent to the area of the general Bow Valley region.

Cairnes (1908) introduced the term "Benton" for marine shales and sandstones along the Bow River and in the Moose Mountain area. Rutherford (1927) split the Benton into its three natural divisions, which he called Lower Benton, Cardium, and Upper Benton. Beach (1943) used this same classification in Moose Mountain area. Hume (1930) showed that the term "Benton" was being misapplied in Alberta, and proposed the names Upper and Lower Alberta for the shale units, retaining the term Cardium for the intervening sandstones but leaving them in the base of the Upper Alberta formation.

Malloch (1911), for the Bighorn Coal Basin, introduced the terms Blackstone, Bighorn, and Wapiabi, in ascending order, to marine shales and sandstones. They are bounded below by the continental Blairmore formation (as now known) of Lower Cretaceous age, and a continental series above, named the Brazeau formation by him, of Upper Cretaceous age.

Rutherford (1927) suggested that his subdivision of the marine section along the Bow River is identical to Malloch's, 120 miles northwest. Webb (1934) showed that Malloch's section is equivalent to that in the south, and, indeed, as far north as the Athabaska River. Since Malloch's terminology has precedence, Rutherford proposed that the terms Blackstone and Wapiabi be retained for the lower and upper shales, but that Cardium be used for the middle sandstones and shales, since the term Bighorn was already in common usage for an Ordovician formation in Wyoming. The Geological Survey of Canada has adopted the name Bighorn throughout the Alberta foothills, apparently considering the name less objectionable than Cardium, a name derived from a common fossil found in the marine sandstones. Moreover, there is no designated type locality for the Cardium, whereas there is for the Bighorn. The Alberta Society of Petroleum Geologists prefers the name Cardium, since it is well established in literature and common usage, and avoids duplication with the Bighorn formation in Wyoming. Therefore, in this paper, the names Blackstone, Cardium, and Wapiabi are used, and they comprise the Alberta Group as proposed by Webb (1934).

[1] Canso Oil Producers Ltd., Calgary, Alberta.


INDEX MAP FOR
ALBERTA GROUP OF THE GENERAL
BOW VALLEY AREA, ALBERTA
FIGURE 1
CROSSFIELD
FIFTH MERIDIAN
GHOST RIVER
BANFF
BOW RIVER
MORLEY
JUMPING POUND FIELD
CALGARY
MOOSE MOUNTAIN
ELBOW RIVER
BOW RIVER
TURNER VALLEY FIELD
SHEEP RIVER
HIGH RIVER
HIGHWOOD RIVER
ALBERTA
BRITISH COLUMBIA
SCALE IN MILES
0 5 10 15 20
MAY, 1956

Malloch (1911) did not give definite type sections for his formations. The sections were measured in the Bighorn Basin on the south fork of Wapiabi Creek, near the junction with the north branch, though neither the Blackstone nor Wapiabi formation is completely exposed. No type section was designated when the term Cardium was introduced, though descriptions were generally based on sections along the Bow River in the foothills. Scott (1947) and others have suggested that a readily accessible section exposed on the Bow River at the Seebe reservoir dam be regarded as the type section.

GENERAL STATEMENT

In this paper the discussion of the Alberta Group will be concerned primarily with the area bounded by the front ranges of the Rocky Mountains on the west, the fifth meridian on the east, the Highwood River on the south, and Ghost River on the north. As has been stated, the Alberta Group can be recognized in the foothills belt from the International boundary in the south to latitude 55 degrees along the British Columbia - Alberta boundary in the north. South of Castle River the Cardium is not a distinct formation. North of Athabaska River an alluvial fan of continental, brackish, and marine sandstone and shale, thickening to the north (Dunvegan formation), splits the Blackstone formation into a lower (Shaftesbury) formation and an upper (Kaskapau) formation.

Webb (1934) divided each formation of the Alberta Group into lithologic zones. It has been found that even where the formations exhibit appreciable variations in thickness, all lithologic zones are readily discernable.

A general eastward thinning of the group is readily observed (Figures 2 and 3) along the Highwood and Bow rivers respectively. Unfortunately, most of the Mesozoic beds have been deeply eroded or completely truncated west of our front ranges. Hence a complete description of the group, and any resultant deductions as to: (a) the site of the land mass which yielded these sediments, (b) where the deepest parts of the basin were, and, (c) the original extent of the Coloradoan seas, are largely conjectural at this time. However, more information is being recorded each year, and some of these questions may be answered for us by historical geologists in the near future.

The thickest sections measured south of the Bow River are on the upper Highwood River west of the front range, and in the Crowsnest Pass area south of Coleman. For the former Carr (1947) reported a thickness of +3,200 feet, and for the latter McKay (1931) reported 3,100 feet. Both sections are badly contorted and these thicknesses therefore may be excessive.

BLACKSTONE FORMATION

THICKNESS

Due to the ease with which the Blackstone is eroded, outcrops are poor except in river channels cutting across the strike. Carr (1947) describes the thicknest section, on the upper Highwood River (locality A, Figure 2), but admits that his figure of 1,100 feet may be excessive, due to the deformed nature of these incompetent beds. Beach (1943) assigns 700 - 800 feet in Moose Mountain area (locality D, Figure 1). This is a generalized section as exposures are poor and individual outcrops do not show the complete formation. Webb (1934) reported a thickness of 900 feet (locality E, Figure 3) after allowing for some repetition due to faulting. The formation becomes thinner eastward as shown on Figures 2 and 3. At the Bearspaw No. 11-3 well in Sec. 3, Twp. 25, Rge. 3, W5th (locality G, Figure 1), it is 755 feet thick, and at the Pine Creek well in Sec. 12, Twp. 20, Rge. 2, W5th(locality C, Figure 1), it is 705 feet.

LITHOLOGY

The formation is essentially a fairly uniform succession of thinly bedded marine shales, which in places become quite sandy with minor fine grained sandstone laminae. Webb's sub-

division into lithologic zones on the Ghost River is as follows:

		Thickness Feet
	Overlying beds — Basal Cardium Sandstone	
Transition Zone	Sandy, dark grey shale with small brown-weathering ironstone concretions along bedding planes, a few thin, very fine grained, hard sandstone ribbons. Rare *Inoceramus* c.f. *corpulentus*. This is the only part of Blackstone that contains numerous rusty, brown-weathering concretions	100
Rusty Shale Zone	Fine grained, sandy, dark grey to black shales, weathering to slightly rusty tinge, containing few concretions which weather yellow-brown, lenticular, and up to 3′ in diameter. Thin bentonite seams. Fossils absent. Underlying shales do not weather rusty	150
Inoceramus labiatus Zone	Finely bedded, black clay shales with very thin, fine grained, grey sandstone laminae. Upper part holds a few lens-shaped grey, calcareous concretions. In middle, discontinuous bands up to 2 feet thick of hard, fine grained calcareous sandstone or argillaceous limestone. These beds are grey to black on fresh surface but weather dirty yellow. Basal portion fine, fissile, black clay shale with a few grey calcareous concretions. Bed of Bentonite and volcanic ash up to 2 feet thick marks base of zone at some localities. *Inoceramus labiatus* Schlotheim is common. *Prionotropis* sp. occurs	300
Barren Zone	Sandy, rusty-weathering shale with thin, hard, sandstone ribbons, and a few thin concretionary, calcareous bands or, at some localities, large masses. Platy to massive sandstone bed up to 4 feet thick occurs about 100 feet above the base. Fish scales generally abundant in sandstone. At base, 2 feet of coarse, conglomeratic sandstone "grit beds" present. Well named "Barren Zone" by Warren & Rutherford as fossils *Inoceramus* cf. *corpulentus* and *Acanthoceras albertense* Warren very rare	350
	Total thickness	900
	Underlying beds — light grey and green sandstones and shales of Blairmore formation.	

One of the most distinct lithologic features of the Blackstone formation lies generally a few feet above the base of the formation in the Bow River area. It is known as the "grit bed" and consists of coarse, angular, quartz and chert grains, and occasional well rounded small pebbles. These sandstones may be present in a few thin stringers or a single bed up to 2 feet thick.

AGE AND CORRELATION

The "grit bed", which occurs at the base of the Blackstone in the foothills, is normally separated from the Blairmore by a few feet of dark marine shales. As well data become available, it is increasingly apparent that this shale interval between grit and Blairmore increases eastward, so that in the vicinity of Calgary it is approximately 60 feet thick. The "grit bed" also, by eastward thickening, becomes part of the Bow Island sandstones of southern Alberta plains or the Viking in central Alberta. Stelck (1952) has shown that the time break between earliest Upper Cretaceous (Cenomanian) and latest Lower Cretaceous (Albian) time is at the "Fish Scale Sand" horizon in Alberta. As we have marine "Colorado" type shales on the plains well below the "Fish Scale Sand" horizon, they must represent Albian time, and reflect marine conditions in central Alberta at an earlier date than in the southern foothills of Alberta, or than Coloradoan time in the United States.

Fish scales and a few teeth are about the only fossils found in the foothills section of lower Blackstone. A sandstone with numerous fish remains occurs in the lower 100 feet in most outcrop sections and in the two wells alluded to in this report. This sandstone is correlated with

the "Fish Scale Sand" of the plains subsurface sections. *Watinoceras* occurs in the Barren Zone. McLearn (1926) and Warren and Rutherford (1928) believed it represents a dividing line between the Cenomanian and Turonian of European chronology. McLearn (1937) further states that the Dunvegan formation north of the Athabaska River is Cenomanian or earliest Turonian. Hence, the Barren Zone at the base of the Blackstone appears to be equivalent in part to the Dunvegan. McLearn (1937) also noted that the *Watinoceras* zone found just above the Dunvegan in the Peace River area represents the first merging in Upper Cretaceous times of the marine seas from the southern United States with the marine seas of northern Alberta.

The *Inoceramus labiatus* zone is widespread and quite fossiliferous. *Prionotropis* is also found in and above this zone. Both these forms, according to Warren (1928) and McLearn (1937), are found in the Coloradoan in the Western Plains region of the United States, and are indicative of Turonian age. The Lower Speckled Shale Zone of the plains seems to be approximately equivalent to the *Inoceramus labiatus* zone. However, in the foothills, calcareous speckled shale is replaced by hard siltstones and occasional sandstones. One of these sandstones is termed the Jumpingpound sandstone in the Bow River Valley region.

CARDIUM FORMATION

The Cardium formation is the most competent one of the Alberta Group. It weathers with difficulty. Therefore, in the foothills wherever the Alberta Group outcrops, prominent ridges generally indicate the position of these sandstone beds. Calgary Power Limited has utilized this relatively durable character of the Cardium formation in several places in the Bow River drainage system to anchor some of its water reservoir dams.

The discovery of oil in the Cardium formation in June, 1953, at Pembina, sparked a tremendous increase in drilling activity in the area adjacent to the foothills belt. This has resulted in additional knowledge of the Cardium over a very large area, and has led to our present knowledge of the eastward thinning of the formation. The fact that the thin wedge of sandstone near the pinchout is much cleaner and better sorted than the thicker, more westerly sections is, of course, one reason for the large oil accumulations at Pembina and other areas to the southeast. This formation is already the reservoir for the largest oil field in areal extent in North America, and may ultimately become one of the largest reservoirs in terms of reserves of oil.

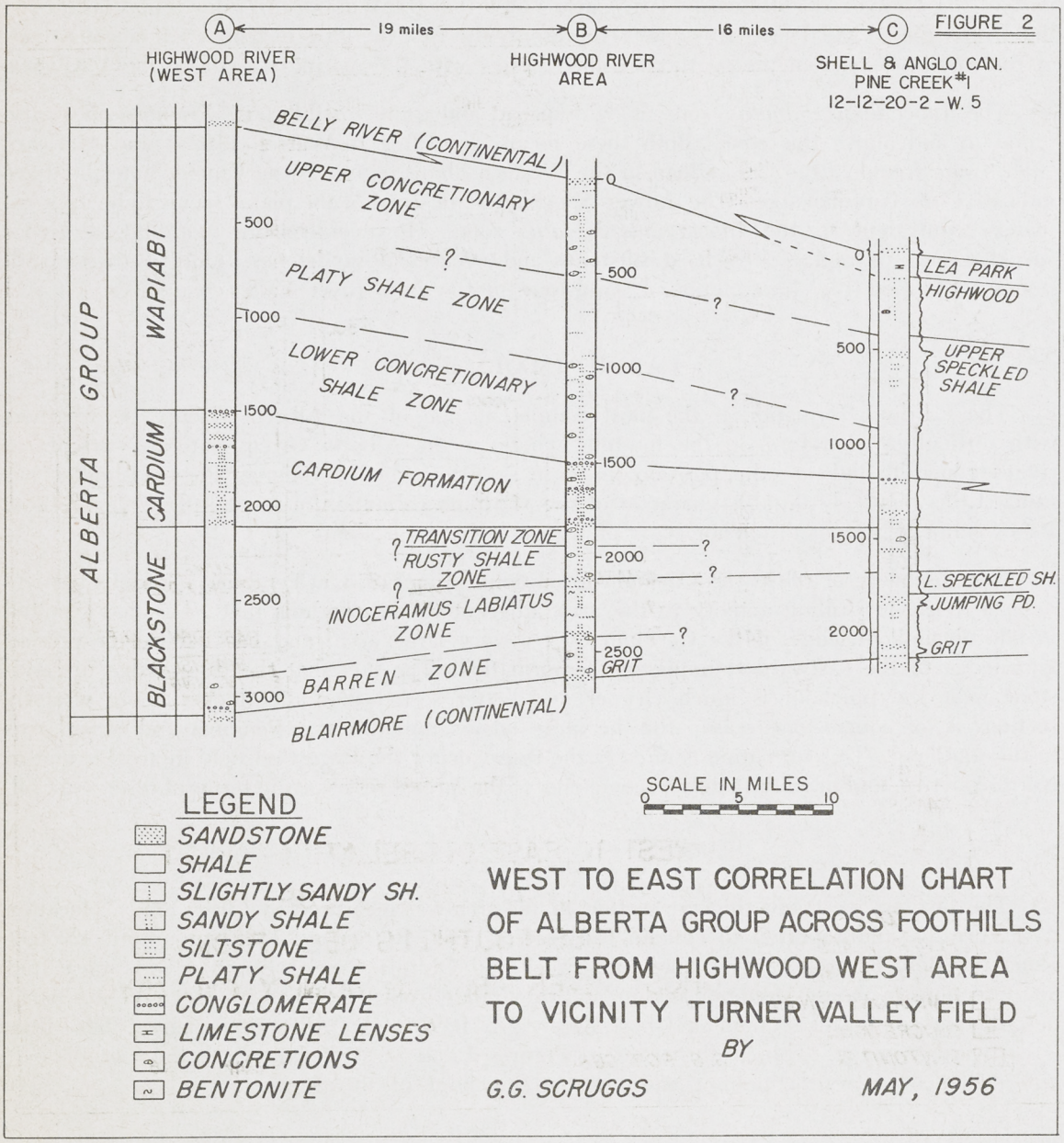
THICKNESS

The farthest west and thickest section in the area was measured by Carr (1947), (location A, Figure 2), and reported to contain 613 feet of beds. Rutherford (1927) reported 220 feet along the Bow River between Kananaskis River and Oldfort Creek. Beach (1943) measured many sections in Moose Mountain region, and they range from 195 feet to 265 feet. Webb (1934) described a composite section on Ghost River, 275 feet thick. All writers agree that there is eastward thinning. This is illustrated in Figures 2 and 3. Well data along the foothills belt also evidence eastward thinning and eventual pinchout of this formation.

LITHOLOGY

The presence of three massive sandstone members is characteristic of the formation in the western part of the foothills, whereas eastward the central sandstone is absent or is represented by shaly sandstones. The upper contact is quite abrupt while the lower is gradational.

A typical section measured by Beach (1943) in Moose Mountain area (locality D, Figure 1) is as follows:



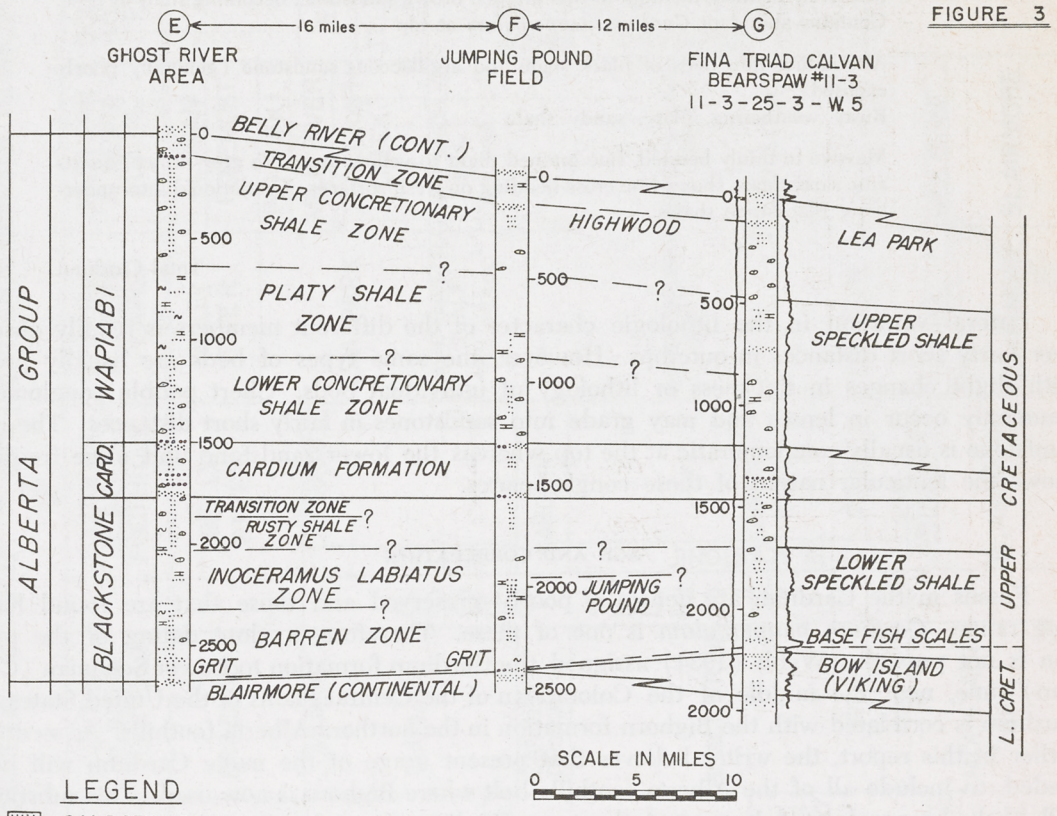
WEST TO EAST CORRELATION CHART OF ALBERTA GROUP ACROSS FOOTHILLS BELT FROM HIGHWOOD WEST AREA TO VICINITY TURNER VALLEY FIELD

BY

G.G. SCRUGGS

MAY, 1956

FIGURE 3



LEGEND

- SANDSTONE
- SHALE
- SLIGHTLY SANDY SH.
- SANDY SHALE
- SILTSTONE
- PLATY SHALE
- CONGLOMERATE
- LIMESTONE LENSES
- CONCRETIONS
- BENTONITE

WEST TO EAST CORRELATION CHART OF ALBERTA GROUP ACROSS FOOTHILLS BELT FROM GHOST RIVER AREA TO VICINITY CALGARY

BY

G. G. SCRUGGS

MAY, 1956

	Thickness Feet
Overlying beds – Wapiabi formation	
Chert and quartz pebble conglomerate	8
Hard, light brownish-grey, fine grained quartzitic sandstone	10
Rusty weathering sandy shale	15
Massively bedded, medium to fine grained brown sandstone, becoming shaly at base. Contains abundant *Cardium pauperculum* at top	34
Alternating thin beds of black shale and argillaceous sandstone (generally poorly exposed)	107
Rusty weathering, platy, sandy shale	45
Massive to thinly bedded, fine grained, light to yellow-brown to grey-brown, quartzitic sandstones, shows fine cross-bedding on fresh surfaces. Gradational into underlying Blackstone shales	8
Total Cardium	227

Lateral variation in the lithologic character of the different members is readily observed over fairly short distances in outcrops. However, the same types of beds are usually present, with slight changes in thickness or lithology of individual beds. Chert pebble conglomerates commonly occur in lenses and may grade into sandstones in fairly short distances. The upper sandstone is usually conglomeratic at the top whereas the lower sandstone unit more frequently shows the lenticular nature of these conglomerates.

AGE AND CORRELATION

Fossils in the Cardium are generally poorly preserved and those that are found have a long range. *Cardium pauperculum* is one of these. Therefore, a close dating of the formation is not possible. Webb (1934) assigned the Cardium formation to Lower Senonian (Coniacian) time, near the middle of the Coloradoan of the Central Plains of the United States. The Cardium is correlated with the Bighorn formation in the northern Alberta foothills. As mentioned earlier in this report, the writer believes that present usage of the name Cardium will be extended, to include all of the Alberta foothills belt where Bighorn is now used. This substitution will likely be accelerated by use of the term Cardium for subsurface sections in wells just east of the foothills belt. It does seem unnecesary to use one name for the subsurface and another for the outcrop of the same formation. Of course, there may always be individuals who prefer one term to the other, but this is not unusual among geologists.

WAPIABI FORMATION

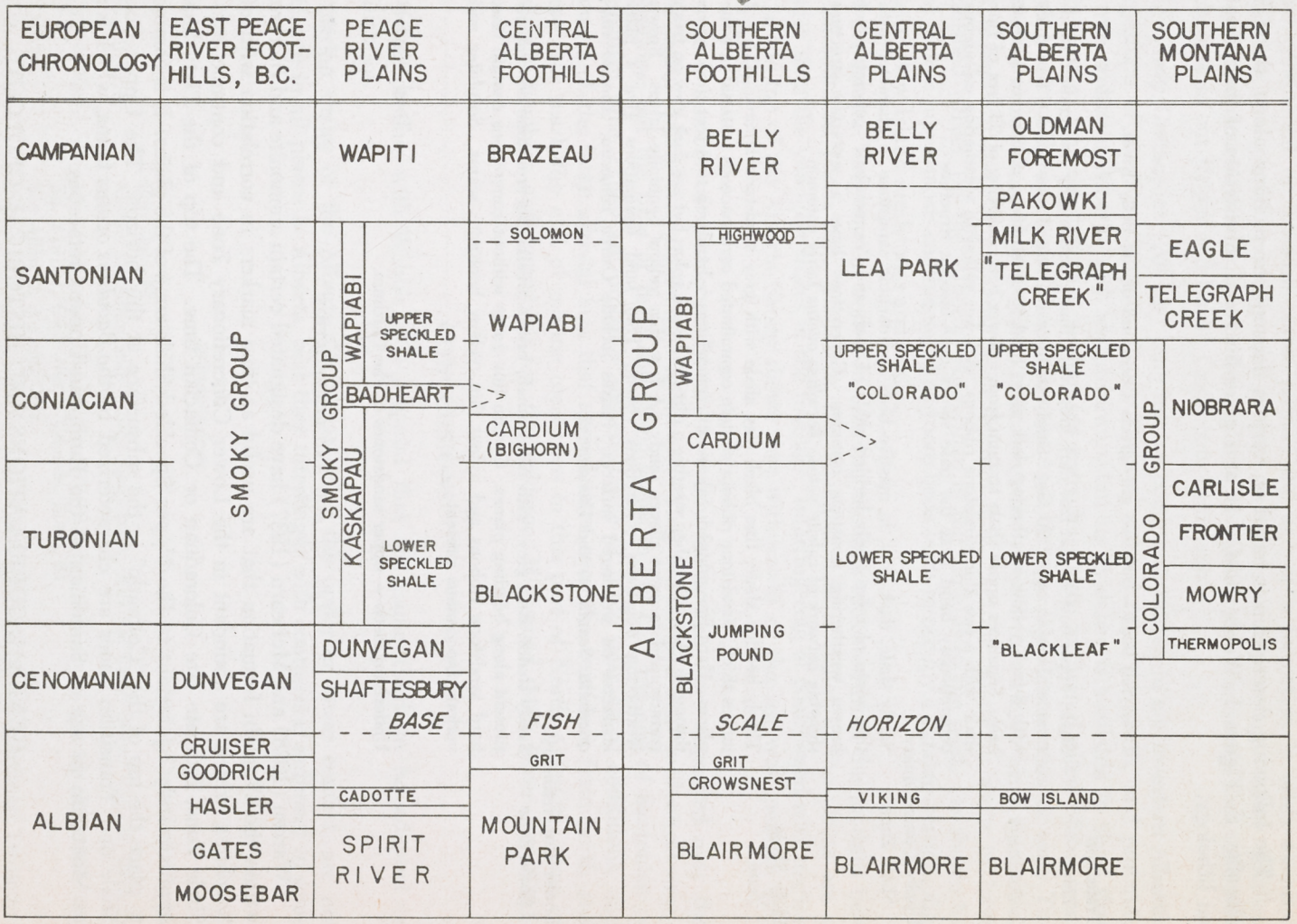
The Wapiabi formation is a succession of marine shales of varying lithologic character, with minor amounts of sandstone. It differs from the Blackstone formation mainly in being appreciably more sandy, less uniformly bedded, and in containing more ironstone nodules more or less concentrated into certain zones. Webb (1934) found these concretionary zones useful in subdividing the Wapiabi.

THICKNESS

Outcrops in the foothills are commonly very poor and, due to intense folding or faulting, are often much contorted. Hence, in any one locality it is nearly impossible to obtain a truly complete Wapiabi section. Along the Bow Valley above Morley, Rutherford (1927) assigned a thickness of 2,300 feet of beds to the Wapiabi formation. More recent studies by Evans (1930), Webb (1934), and Beach (1943) have resulted in lower totals, so that now 1,400 to 1,500 feet

FIGURE 4

CORRELATION CHART ALBERTA GROUP – BRITISH COLUMBIA TO MONTANA



seems to be more nearly correct. Carr (1947) also found 1,500 feet on the upper Highwood, west of the front range of mountains.

LITHOLOGY

The following description is based on various incomplete sections along the Ghost River (locality E, Figure 1, Webb, 1934). It also gives his zonal subdivision of the formation based on lithology.

		Thickness Feet
	Overlying beds — massive grey-green sandstones of the Belly River.	
Transition Zone	Shale, uppermost 40 feet fine dark grey, with thin greenish-grey fine grained sandstone ribbons in upper 20 feet. Sandy shale or shaly sandstone band 6 feet thick with 8-inch yellow weathering dark grey, hard, concretionary, calcareous band at base. Separates upper shale stratum from a lower bed consisting of 74 feet of fine shale with a few thin sandstone ribbons. A lower yellowish weathering calcareous concretionary band near the base shows cone-in-cone structure	120
Upper Concretionary Shale Zone	Sandy shale, dark grey, in massive beds approaching sandstone in character with thin zones of more finely bedded shale. Layers and "cannon-ball" concretions of brown weathering ironstone common. Concretions have a septarian structure showing network of calcite veins. *Baculites ovatus* fairly common	430
Platy Shale Zone	Thinly bedded shale, fine black clay shale with grey sandstone laminae, 0.5 - 2 inches thick. Sandstone ribbons contain comminuted carbonaceous material in some places. Hard fine grained, calcareous, concretionary bands up to 3 feet thick occur throughout the zone; they weather a dirty yellowish color, but are dark grey on fresh surface, and in some places sandy. A few thin yellow bentonite layers. Brown weathering ironstones concretions absent. Thin sand laminations give a platy character on weathered surfaces. Fossils include *Ostrea congesta, Anomia subquadrata, Scaphites,* and *Inoceramus*	450
Lower Concretionary Shale Zone	Sandy shales, dark grey, with many small, brown weathering ironstone concretions present along bedding planes. Certain thin zones without concretions contain fine, hard sandstone ribbons and a few thin, yellow bentonite seams. *Scaphites* and various *Inoceramus* present	400
	Total Wapiabi	1,400
	Underlying beds — upper sandstones of the Cardium.	

AGE AND CORRELATION

Warren (1928) and McLearn (1937) have designated certain ammonite and *Inoceramus* zones within the Wapiabi formation that are useful as time markers in correlation with other areas. *Scaphites,* which are abundant in the Lower Concretionary Zone and continue into the Platy Shale Zone, indicate late Coloradoan or Coniacian time. The top of the Platy Shale Zone is approximately equivalent to the Upper Speckled Shale zone of the plains. It is common practice to place the top of the "Colorado" in the subsurface at this horizon. The Upper Concretionary Shale and Transition zones are characterized by the *Baculites ovatus* fauna, which is recognized as Montanan in age or Santonian of the European Upper Cretaceous.

GENERAL CORRELATIONS AND HISTORICAL GEOLOGY OF THE ALBERTA GROUP

Writers do not all agree as to correlatives of the Alberta Group. A correlation chart (Figure 4) presents the general opinion of most present day geologists. Some generalities have neces-

sarily been made, as different correlations are possible. The upper and lower boundaries of the Alberta Group present the major problems, because marine conditions prevailed in some areas while continental or near shore conditions prevailed at others. Since marine faunas are usually quite unike continental or brackish water faunas, the age of a formation is often assumed from its relative stratigraphic position with respect to others of known age. More detailed lithologic and faunal studies will have to be made to correlate more accurately the multitude of facies changes in our Upper and Lower Cretaceous sediments.

In late Lower Cretaceous (Albian) time marine conditions existed in northwestern Alberta, during deposition of the Fort St. John Group.The sea entered from the north, and probably extended into southern Alberta and Saskatchewan, but no evidence is available to show that this Arctic sea was connected with a similar sea extending into northern United States from the Gulf of Mexico. However, definite similarities exist between late Cenomanian or early Turonian faunas of Canada and United States, indicating that these two seaways were connected, and that the southern and Arctic faunas were intermingling. Marine condition seem to have been established earlier on the Alberta plains than in the foothills to the west, (as shown by Figure 3), where uppermost continental Blairmore beds seem to occupy a similar stratigraphic position to the Bow Island sandstones and shales.

When the marine environment ended in Alberta, the seas retreated from the foothills belt first and the southern plains last. Therefore, the youngest marine shales in the plains are a little younger than the youngest shales in the foothills. Interfingering of continental with marine sediments in the top of the Alberta Group shows that withdrawal of the sea was gradual, and often interrupted.

There are a number of marine sandstones or sandy facies that were deposited near the close of the marine phase of sedimentation in Alberta. They are not all found in identical stratigraphic positions, but the time of their deposition seems to fall near the end of Santonian or early Campanian time. They are probably representative of fairly near shore conditions, and are forerunners of the large alluvial fans that spread later over the continent from north and west. These fans mark the end of marine conditions in this part of North America. Some of these sandstone members and formations are the Solomon, Highwood, Milk River ,and Eagle sandstones.

CONCLUSIONS

1. The writer concurs with Webb's 1934 proposal that the name Cardium be adopted in place of Bighorn.

2. The marine shales of the Alberta Group, at either the upper or lower contact, are not identical in age in all places in Alberta, and they interfinger with continental sediment to some degree.

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BIGHORN FORMATION IN THE CENTRAL FOOTHILLS OF ALBERTA[1]

DONALD F. STOTT[2]

A study of the Upper Cretaceous Alberta group in the southern and central foothills has been undertaken by the writer for the Geological Survey of Canada, to determine the lateral and vertical changes in lithology and the distribution and succession of the faunas. This paper summarizes some of the results obtained from the study of the Bighorn formation of the Alberta group in the central foothills, between the Ram River (latitude 52°) and Smoky River (latitude 54°), during 1954 and 1955. As only two of the three field seasons have been completed, the discussion is of a general nature.

From the time work was begun in the foothills, various names have been applied to the sandstones which separate the shales of the Blackstone formation from the shales of the Wapiabi formation, the basal and upper formations respectively of the Alberta group. Cairnes (1907), who used the term Cardium sandstones, stated, "Specimens of *Cardium pauperculum* are so plentiful in this sandstone series that Dr. Hector, in 1858, called the whole series along the Bow River, including the Claggett and Niobrara-Benton, the Cardium shales". As pointed out by Harris (1954), no such reference can be found in Hector's published papers and "therefore the name as it is used today was defined by Cairnes". Beds in a similar stratigraphic position in the Bighorn basin were assigned to the Bighorn formation by Malloch (1911), who examined the coal deposits in the foothills between Saskatchewan and Brazeau rivers. He stated, "the Bighorn formation is named after Bighorn Creek, on which it outcrops just below the junction of the two branches". The formation was said to consist of "siliceous and shaly sandstones, black and brown shales, and several bands of conglomerate". Malloch did not indicate a type section but described a section "on the more southerly of the two main branches of Wapiabi creek". Rutherford (1927), in a report on the geology along the Bow River between Cochrane and Kananaskis, was the first to give formational status to the Cardium beds. He suggested the correlation of the Cardium formation with the Bighorn formation as mapped further north.

The designation Cardium sandstones or formation has been used for the sandstone unit in the southern foothills (Cairnes, 1907; Hume, 1929; Beach, 1943); to a lesser extent in published reports in the central foothills (Evans, 1930; Webb and Hertlein, 1934; Scott, 1951); and almost exclusively in the northern foothills of Alberta (Gleddie, 1954; Stelck, 1955). Many oil companies use this name in their subsurface studies. The term Bighorn formation has been used in the central foothills (McKay, 1940; Hake et al, 1942; Henderson, 1944), and the Geological Survey of Canada (Hage, 1941; Douglas, 1950) and the Alberta Research Council (Clow and Crockford, 1951) have extended its usage through the southern foothills.

For the present study, Bighorn is preferred because the writer commenced his studies in the area of the original Bighorn, and because some uncertainty exists as to the stratigraphic interval included in the Cardium formation as used in the north by Gleddie (1954) and Stelck (1955), and that originally included by Cairnes (1907).

The stratigraphic interval of the Bighorn formation as found in the Blackstone River-Chungo Creek area is considered to be the most satisfactory at present. In the area east of the Bighorn range where these studies were made, the lower boundary of the formation is drawn by the writer at the base of the thick sandstone unit which lies below beds of brackish or nonmarine sediments. Correlation with sections along the eastern edge of the first range indicate that other sandstone units are present at lower stratigraphic positions, and these are believed to be equivalent to part of the Concretionary Zone that comprises the uppermost unit

[1] Published by permission of the Acting Deputy Minister, Department of Mines and Technical Surveys, Ottawa

[2] Graduate student, Princeton University, New Jersey.

of the Blackstone formation. Comparison of thicknesses and fossil evidence confirm this correlation.

The upper contact of the Bighorn formation is drawn at the top of the uppermost fine-grained sandstone unit and below the pebble and grit beds that are usually present within the basal shales of the Wapiabi formation. These grit beds are considered to be the first deposits of the transgressing Wapiabi sea. The contact is sharp and well defined, although the upper surface of the Bighorn formation may be slightly uneven with pebbles embedded in reworked sand. This boundary differs from that of the Cardium formation in the Peace River region as described by Stelck (1955), in which he places the upper contact at the top of the conglomerate (Baytree member).

The thickness of the Bighorn formation ranges between 332 feet on Littlehorn Creek to 188 feet on Little Berland River. In general, the thickness is fairly constant in a northwest-southeast direction but decreases from west to east. Reports of thicknesses greater than approximately 350 feet are probably the result of including sandstones of either the Wapiabi or Blackstone formation in the Bighorn formation. The report of 485 to 808 feet thickness, near Solomon Creek in the Entrance Map Area, by Lang (1947), is based on a poorly exposed section in which there is a fault. An upper sandstone unit on Muskeg River mapped as Bighorn by Irish (1951)is considered to be part of the Wapiabi formation and probably equivalent to the Badheart sandstone of the Peace River area.

The Bighorn formation consists of fine-grained sandstone, dark grey shale, some greenish-grey shale and minor beds of conglomerate. The lithology remains fairly constant for considerable distances along the regional strike, but may change rapidly across it. Two sections will serve to illustrate some of the variations which were found. The formation is divided into several units which are discussed in the following paragraphs. These subdivisions are of an informal nature and are used for convenience only in the present discussion.

Section 1. Bighorn Formation

Grave Flats Map Area, Alberta; Thistle Creek, east flank of syncline, near Brazeau River, Twp. 44, Rge. 20, W5th.

Bed	Lithology	Thickness (feet)	Height Above Base (feet)
	Wapiabi Formation		
4	Grit, light grey, with concretionary upper surface, orange weathering. Basal foot is almost all concretionary.	8	22
3	Shale, sandy to gritty, with bands of concretions, 8″ x 12″-18″. Less sandy in basal foot.	7	14
2	Grit, light grey, grading into concretions in some zones, massive, rusty weathering.	4	7
1	Grit, 60%, and shale. Grit is thinly bedded, and contains some pelecypod fragments.	3	3
	Bighorn Formation		
	Upper Sandstone		
33	Sandstone, fine-grained, brownish grey, rusty weathering, slightly laminated, massive, with 6″ concretionary band at 18′.	24	253
32	Shale, silty, dark grey, banded appearance, with 3″ x 6″ concretions at base.	3	229
31	Sandstone, fine-grained, slightly laminated, massive, rusty weathering, light grey, 2″-3″ concretionary bands poorly developed at base.	8	226
30	Siltstone, 40%, very argillaceous, and shale, bedded appearance, dark grey.	8	218
29	Sandstone, fine-grained, bluish grey, finely laminated, 1′ bed at top, 2′ bed at base, with shale partings in centre, few 2″ x 4″ concretions at base.	5	210

Bed	Lithology	Thickness (feet)	Height Above Base (feet)
28	Sandstone, fine-grained, bluish grey, in 4"-6" bands, 50%, and silty shale. Bed has a banded appearance.	8	205
27	Sandstone, 25%, and shale as above.	12	197
26	Sandstone, fine-grained, homogeneous, light brownish grey, weathers rusty, thickly bedded.	7.5	185
25	Shale, silty, papery, dark grey, underlain by 3" sandstone, fine-grained, very thinly bedded.	0.5	177.5
24	Sandstone, fine-grained, light grey, rusty tan weathering, massive, homogeneous.	4	177
23	Shale, silty, platy, grading into sandstone in some zones.	1	173
22	Sandstone, fine-grained, homogeneous, massive, light grey, rusty tan weathering, cut and fill features at base.	3	172
	Brackish or Nonmarine Beds		
21	Sandstone, 50%, fine-grained, laminated, cross-bedded, light grey, and shale.	1	169
20	Shale, greenish to brownish grey, coaly in upper 2" (not continuous) and at 2'.	3.5	168
19	Siltstone, greenish grey, porous, with some plant fragments.	1.5	164.5
18	Shale, silty, greenish to brownish grey, blocky. Plant fragments in basal foot.	3	163
17	Siltstone, greenish to brownish grey, blocky, becoming platy towards base. Plant fragments at top.	2	160
16	Sandstone, brownish grey, dirty, fine-grained, homogenous, massive, rusty weathering.	4	158
15	Sandstone, fine-grained, laminated, grey, thinly bedded to shaly, with plant fragments.	3	154
14	Sandstone, brownish grey, laminated, fine-grained, massive with few 1"-2" thinly bedded sandstone partings.	5	151
	Upper Marine Shale		
13	Shale, silty, dark grey. In upper 7', shale is platy and contains few hard siltstones. Remainder is blocky to rubbly with few concretions.	32	146
	Middle Siltstone?		
12	Mostly covered. Shale, silty, dark grey.	27	114
	Brackish to Nonmarine Beds		
11	Sandstone, fine-grained, brownish-grey, homogeneous, massive.	2	87
10	Shale, brownish to greenish grey. Partly covered.	7	85
9	Sandstone (75%), medium to fine-grained, brownish grey, homogeneous. Beds are 4"-12" thick.	7	78
8	Siltstone, sandy, greenish.	4	71
7	Sandstone, coarse to gritty, with concretionary band at base.	2	67
6	Shale, greenish grey. Interval is partly covered. Greenish sandstone occurs at 20' and coaly shale 5' from top.	27	65
	Basal Sandstone		
5	Sandstone, medium-grained, homogeneous, massive, some carbonaceous inclusions.	20	38
4	Shale, coaly and thinly bedded sandstone.	1	18
3	Sandstone, fine-grained, laminated, massive, large scale cross-bedding, light grey, tan weathering.	6	17
2	Shale, silty, dark grey, and some platy sandstone.	3	11
1	Sandstone, fine-grained, light grey, laminated, thickly bedded.	8	8
	Blackstone Formation		
	Shale, silty, banded, dark grey with concretionary bands.		

Section 2. Bighorn Formation

George Creek Map-Area, Alberta; Chungo Creek, 3 miles east of gap in Bighorn Range, Twp. 43, Rge. 18, W5th.

Bed	Lithology	Thickness (feet)	Height Above Base (feet)
	Wapiabi Formation		
2	Shale, very silty, blocky, rusty weathering, massive appearance.	11	23
1	Grit, greenish grey, concretionary, with some siltstone, and small pebbles at base.	12	12
	Bighorn Formation		
	Upper Sandstone		
34	Sandstone, homogeneous, light grey, fine-grained, thickly bedded, tan weathering.	4.5	251
33	Sandstone, homogeneous to slightly laminated, fine-grained, light grey, porous, thickly bedded.	16.5	246.5
32	Shale ,silty, blocky, dark grey.	0.5	230
31	Sandstone, laminated, cross-bedded, light grey, fine-grained. Three inches of shale at base.	4.5	229.5
30	Sandstone, laminated, fine-grained, massive. Base is irregular, shows cross-bedding, and contains 2″-3″ shale pockets.	5	225
29	Sandstone, laminated, light grey, massive, large cross-bedding, with well defined 4″ papery shale at base.	4.3	220
28	Sandstone, laminated, fine-grained, light grey, massive, cross-bedded.	2.7	215.7
27	Shale and well indurated siltstone, 50%, and few concretions.	3	213
26	Sandstone, laminated, fine-grained, brownish to light grey, massive, cross-bedding more pronounced towards base.	11	210
	Upper Shale		
25	Siltstone, argillaceous, dark grey, somewhat calcareous, thinly bedded to platy, pyritic spots.	6	199
24	Sandstone, laminated, fine-grained, light grey, in ellipsoidal lenses, 2′ x 4′.	2	193
23	Siltstone, very argillaceous, bedded to blocky, with concretions, 3″ x 6″, poorly developed.	9	191
22	Siltstone, very argillaceous, grading into silty shale, chunky, with bands of sandstone, fine-grained, dense, becoming concretionary in centre. Grades into underlying beds.	29	182
21	Shale, silty, with thin siltstone bands and concretionary zones.	24	153
20	Shale, rubbly, dark grey, becomes more silty in basal 3′, contains some concretions.	21	129
	Middle Siltstone		
19	Siltstone, argillaceous, dark grey, massive, greenish grey weathering, more shaly in basal 9 feet, with some concretions.	29	108
	Brackish or Nonmarine Beds		
18	Sandstone, homogeneous, brownish grey, fine-grained, rusty-orange weathering, blocky.	1	79
17	Sandstone, 50%, fine-grained, calcareous, brownish grey, and shale. Beds are 1″-3″ thick and contain plant fragments at top.	7	78
16	Shale, silty carbonaceous.	1	71
15	Sandstone, fine-grained, homogeneous, brownish grey, massive, large scale cross-bedding, calcareous at top with carbonaceous material.	5	70
14	Shale, and sandstone, thinly bedded.	0.5	65
13	Sandstone, laminated, fine-grained, brownish grey, calcareous, large scale cross-bedding, with carbonaceous inclusions.	6.5	64.5

Bed	Lithology	Thickness (feet)	Height Above Base (feet)
12	Shale, greenish brown and rubbly in upper foot, silty and dark grey at base. Three inch carbonaceous and coaly band at top, and two inch band at 1′.	3	58
11	Shale, argillaceous, dark grey, containing numerous polecypods and plant fragments. Three inch coquina band at 2½′.	3	55
10	Shale, rubbly, with concretions at top.	4	52
9	Siltstone, well indurated, greyish weathering.	0.5	48
8	Shale, silty ,rubbly, with 3″ coaly shale in centre.	4.5	47.5
7	Sandstone, well indurated at top, becoming argillaceous towards base, laminated, fine-grained.	4	43
6	Shale, silty, rubbly, dark grey.	4	39
5	Sandstone, laminated, fine-grained, light grey, carbonaceous, massive, with plant imprints on basal surface.	2.5	35
4	Shale, silty, rubbly. Top 2″ and basal 4″ are coaly.	3.5	32.5
	Basal Sandstone		
3	Sandstone, homogeneous, fine-grained, light grey, extremely carbonaceous in upper 4″.	4	29
2	Sandstone, fine-grained, light grey, thickly bedded, with thin beds, cross-bedding, and cut and fill features in basal one foot.	10	25
1	Sandstone, homogeneous to laminated, massive bedded, light grey to brownish grey, fine- grained.	15	15
	Blackstone Formation		
	Shale, and interbedded siltstone, dark grey, rusty weathering.		

The fine-grained basal sandstone unit is continuous throughout the area. The sand grains, which are subangular to angular, consist mainly of quartz with some chert. The sand is fairly clean with minor quantities of clay matrix. Bedding is uniform, and some of the beds are finely laminated.

The basal sandstone, which is marine, is overlain by brackish or nonmarine beds consisting of greenish grey shales with thin beds of coal and some thin sandstone beds. Toward the east, these beds grade laterally into carbonaceous sandstone showing fine cross-bedding. In the Canyon Creek-Blackstone River area, this part of the sequence may be mistaken for basal sandstone. Brackish conditions apparently continued in the western part of the area longer than in the east as marine shales are found in eastern sections in an equivalent position. Jeletzky, of the Geological Survey of Canada, comments on the fossils from the nonmarine beds as "a peculiar association of brackish or fresh water pelecypods and gastropods allied to the brackish to nonmarine faunal elements of the Dunvegan formation as well as to those of the nonmarine formations of the Wapiti and Brazeau groups and their equivalents".

One of the best markers in the Brazeau River region is the middle siltstone or sandstone. This consists of approximately 20 feet of dark grey argillaceous to sandy siltstone which weathers to a greenish rust colour. Large orange-weathering concretions are present. Toward the west, this unit grades into nonmarine beds and loses its distinctive characteristics.

A widespread marine transgression appears to have occurred after the deposition of the siltstone. Throughout the southern part of the area, the upper marine shale unit consisting of dark grey shale with orange-weathering concretions, is found above the middle siltstone. In the west, marine conditions, represented by these deposits, later gave way to nonmarine deposition with the development of a second unit of greenish grey shale, minor coal, and carbonaceous sandstone.

The youngest beds included in the Bighorn formation consist of fine-grained sandstone resembling that of the basal unit, but containing more clay matrix. This upper sandstone unit decreases in thickness and tends to grade into shale toward the east.

In the vicinity of Athabasca River, coarse-grained sandstone is present in several thick beds between the basal and upper sandstone units, and appears to be a facies equivalent to the nonmarine shales to the south. On Muskeg River, the whole section above the basal sandstone consists of brackish or nonmarine sediments.

The age of the Bighorn formation is quite well established. *Scaphites* identical with or comparable to *Scaphites preventricosus* Cobban have been collected from beds at the base of the Wapiabi formation immediately above the Bighorn formation. Jeletzky comments:

"This species is the index of the earliest Niobrara zone of the United States Western Interior region which appears to be of early Coniacian age in terms of the International Standard stages. Within the refined zonal succession of Cobban (1951) this zone immediately overlies the *Prionocyclus (Collignoniceras)* zone and is in its turn overlain by the restricted *Scaphites ventricosus* and *Inoceramus umbonatus* zone".

Fossils collected from the Bighorn formation are said by Jeletzky to include:

"*Inocerami* comparable with *Inoceramus fragilis* Hall and Meek and *Inoceramus* ex gr. *lamarcki Park* comparable with or close to *Inoceramus corpulentus* McLearn. In the Western Interior region of the United States (Cobban, 1951) and Canada such *Inoceramus* forms seem to be coeval with *Prionocylus (Collignoniceras)* . . . . (These fossils) are thought to be late Turonain in age. The occurrence of belemnoids comparable with *Actinocamax* aff. *strehlensis* Jeletzky further supports this suggestion".

Thus, the Bighorn formation of the central Foothills appears to be late Turonian in age, and is overlain above a slight break by deposits of early Coniacian age.

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THE NON-METALLIC MINERAL RESOURCES OF THE COCHRANE-CANMORE AREA ALBERTA

J. G. MATTHEWS[1]

The non-metallic mineral resources of the Cochrane-Canmore area have contributed very substantially to the industrial welfare of Alberta. In particular, the construction industry has virtually been dependent upon the mineral products of this region.

Limestone is quarried for the manufacture of Portland cement and lime, and for use as a filler for asphalt products, a weighting material in oil-base drilling muds, in the preparation of mineral feeds for livestock, and for rip-rap; shale is quarried for use in the manufacture of cement and Ytong; sand and gravel are used for railway ballast and highway construction; and sulphur[2] is extracted from natural gas for use chiefly in the paper and pulp industry and in concentrating uranium ore.

In the past, there has been production of rock wool and light weight aggregate from shales found in the area, of bricks from clay, and building stone from tufa and sandstone.

LIMESTONE

Limestone has been quarried for the manufacture of Portland cement at Exshaw for the past 50 years. At the present time the daily requirements of stone amount to more than 2,000 tons.

The rock being quarried is in the upper part of the Palliser formation, and consists of a series of limestone beds variable both as to thickness and quality. The magnesium oxide content of the thicker beds generally is about 1 to 2 percent; some of the thin beds may have as much as 10 to 12 percent magnesium oxide. The beds strike about N 30° W with a dip of about 45° to the southwest. By taking a wide horizontantal cut through all the beds, a mixture of stone within the limits for magnesium oxide can be ol cut through all the beds, a mixture of stone well the cement plant would run 1.0% SiO_2, 4.0% Al_2O_3, 0.2% Fe_2O_3, 52.9% CaO, 1.9% MgO, and 43.4% loss on ignition.

Two quarries are being operated, a lower one adjacent to the highway, and an upper one (about 500 feet higher in elevation) located on top of the mountain immediately north of the plant. The latter quarry has been developed in recent years.

During the years 1906 to 1914, the Alberta Portland Cement Company, with a plant in Calgary, operated some limestone quarries in the Rundle formation on the south slope of Grotto mountain. Goudge (1944) reports that several quarries can be found on two limestone ridges that trend along the south side of the mountain. A very fine-grained, dark-grey, massive, high-calcium stone was quarried. In the lower ridge, there is a section 75 feet thick of high-calcium stone. In the upper ridge, separated from the lower by 100 feet of cherty limestone and siliceous dolomite, the high-calcium stone is only 20 feet thick.

At Kananaskis, Loders Lime Co. Ltd. quarries Cambrian limestone for the manufacture of lime and crushed stone products. This plant has been in operation for more than 70 years. In this vicinity, the Cambrian consists of a series of thin alternating beds of magnesian limestone and dolomite with a few high-calcium beds. The degree of dolomitization varies both across and along the bedding, even in the high-calcium beds, but to a much lesser extent in these.

There are at least three bands of dense, pale grey, high-calcium limestone on the property. These vary in width from 40 to 80 feet and are separated from each other by from 75 to 150 feet of magnesian limestone.

[1] Project Engineer, Western Minerals Ltd., Calgary.
[2] Sulphur is treated elsewhere in the guide book.

The steep-dipping attitude of the bands (75 to 80 degrees to the southwest) and their small width necessitate mining along the strike. Quarries are operated on the two lower bands. Generally, the proportions of silica and other impurities are very low not only in the high-calcium stone but in the intervening magnesian limestone bands as well. The chief variation is the lime-magnesia ratio. Stone containing more than 98% $CaCO_3$ and less than 1% each of insoluble matter and $MgCO_3$ can be obtained. Whenever specifications for the product permit, rock adjoining the high grade bands is taken, thus enabling a more economical quarry operation.

Quarried stone that is too fine for feeding to the lime kilns is pulverized for use mainly as a filler in asphalt roofing, a weighting material in oil-base drilling muds, and in the preparation of blended mineral feeds for livestock. Coarse magnesian stone is used for rip-rap.

Goudge (1944) makes reference to a company known as the Gap Lime Works which, prior to 1913, quarried high-calcium limestone on the southern slope of Grotto mountain for the production of lime.

SHALE

The largest shale quarry in the area is operated by the Canada Cement Company on the north side of the Canadian Pacific track at Seebe. Hard black shale of the Wapiabi formation is quarried and hauled by rail to the cement plant at Exshaw.

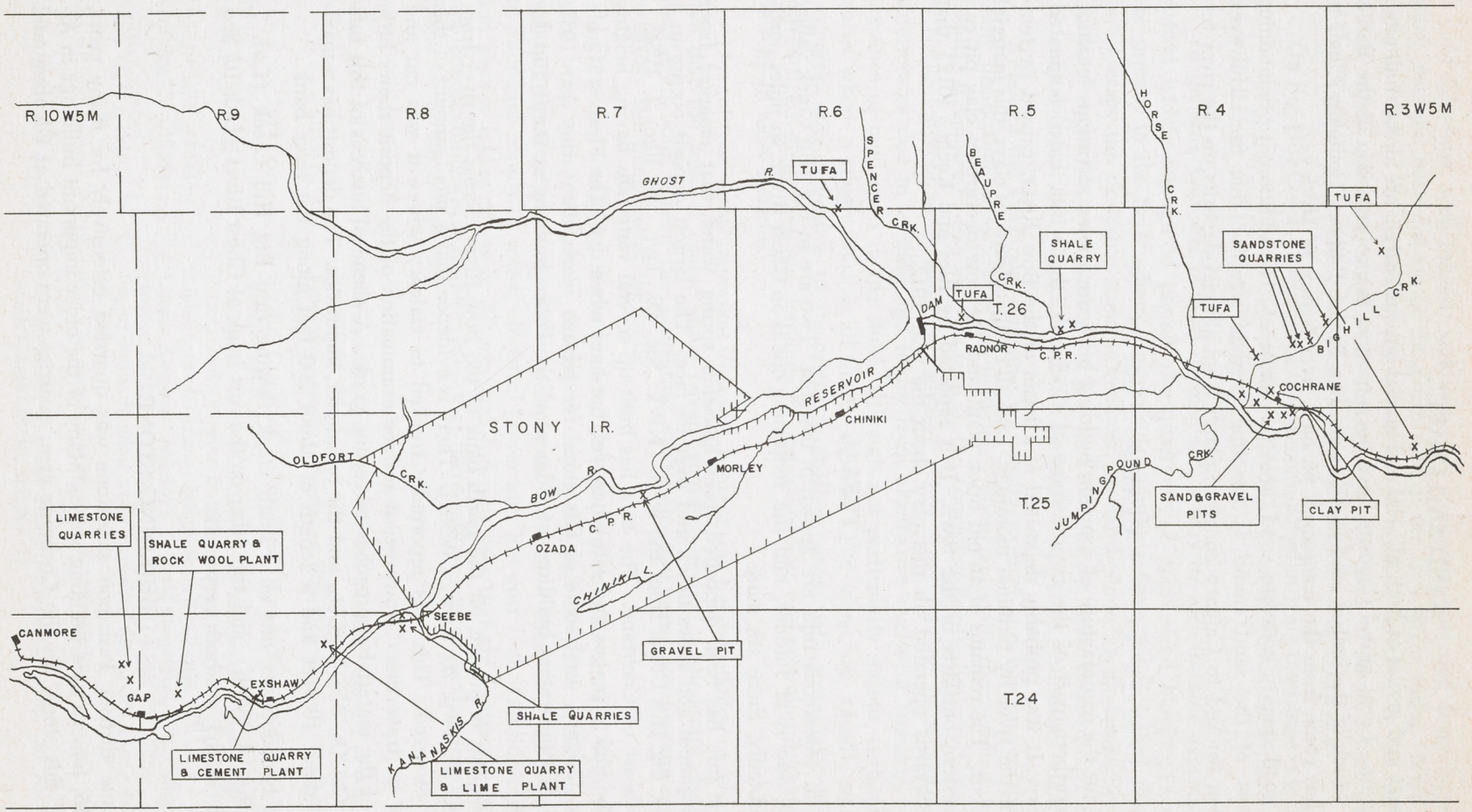
The beds in the quarry strike SE-NW and dip to the southwest at an angle of about 15 degrees. The maximum amount of overburden at the quarry site is about 8 feet.

This shale contains numerous siliceous beds, especially on the west side of the quarry. Because of the high silica content of some of the beds, the shale is excavated selectively. A typical analysis of the material as supplied to the cement plant is 65.5% SiO_2, 13.3% Al_2O_3, 5.1% Fe_2O_3, 2.0% CaO, 2.2% MgO and 7.1% ignition loss.

Directly opposite the cement company's quarry, on the south side of the Canadian Pacific track, a small shale quarry has been opened by The Alberta Ytong Manufacturing Company, Limited. The shale, which is the same as that quarried by the cement company, is hauled by rail to Calgary. It is used to manufacture Ytong, a lightweight cellular building material. In this process, the shale is finely ground and mixed with pulverized lime in the ratio of 3 to 1. Water in the proper proportion, and a chemical foaming agent are added, and the mixture is poured into steel moulds where it rises and presets. It is then cut into blocks of desired dimensions and steam cured. The formation of gas bubbles gives Ytong its cellular structure, excellent insulating qualities, and exceptional lightness.

Calcareous shale suitable for the manufacture of a rock wool is found in the Banff formation. Several years ago a quarry and plant were opened at Gap Lake, about 3½ miles by road west of Exshaw. This plant operated until early 1953, producing a granulated wool. While the plant was in production, shale was used at the rate of approximately 5,000 tons per season. A dolomite flux was obtained from a small exposure several hundred yards east of the shale quarry. Approximately 1.6 tons of shale and 0.2 tons of dolomite flux were required for each ton of rock wool produced.

Shales of the Belly River formation are known to be suitable for the manufacture of lightweight concrete aggregate. Unfortunately, these beds are usually thin, inclined, and interbedded with heavy sandstone layers so that quarrying costs are excessive. During 1954, Belly River shale was quarried on the north side of the Bow River at the mouth of Beaupre Creek (SE¼, Sec. 15, Twp. 26, Rge. 5, W5th), approximately 8 miles by road west of Cochrane. This material was trucked to the lightweight aggregate plant of Renn Expanded Aggregates Limited, Calgary.



NON METALLIC MINERAL RESOURCES

CANMORE – COCHRANE AREA, ALBERTA.

SCALE IN MILES

0 1 2 3 4 6 8

FIGURE 1.

SAND AND GRAVEL

Reserves of sand and gravel of both alluvial and glacial outwash origin are almost unlimited throughout the region. Local gravel deposits have been used in the construction of the Banff-Calgary highway. Much of the ballast used on the Canadian Pacific Railway Company's lines in Southern Alberta has come from the company's pit on a river terrace at Morley.

Deposits of good quality concrete sand are very scarce. In addition to containing too much silt, most of the sand found is too fine in grain size for this use. However, some sand has been trucked to Calgary concrete plants from alluvial deposits on the river terrace at Cochrane.

CLAYS

Clays suitable for the manufacture of common building brick are known at various localties.

Beneath the northern part of the river terrace at Cochrane, there is a hard, laminated, silty, calcareous clay. It was probably deposited in a basin of the Bow River, caused by temporary damming of the river by terminal moraines. Like all richly calcareous clays, this material burns to a buff colour. The remains of an old brick plant and the now overgrown clay pit can be seen on the western outskirts of the town. It is reported by Ries and Keele (1912) that three common brickyards operated on this clay about the year 1912.

TUFA

Four deposits of calcareous tufa are known in the area. Two are in Big Hill Creek valley north of Cochrane, one is at Radnor, and the remaining one is on Ghost River, six miles north of Chiniki. Undoubtedly, there are more.

In all cases the tufa has been deposited from lime-rich spring water that emerges from the side of an escarpment and flows down and over its face. The largest deposit occurs in a small draw entering Big Hill Creek from the west (NW¼, Sec. 29, Twp. 26, Rge. 3, W5th), about 6 miles northeast of Cochrane. The tufa has built up several waterfalls having heights of 15 to 20 feet. The rock is porous and soft when wet, but hard when dry. The Flesher Marble and Tile Company, Calgary, used some of this stone for terrazo work about the year 1935. It was used in the Administration buildings at Edmonton, the Police building at Banff and the Armory in Calgary.

A small tufa deposit is present on the north bank of the Bow River, across the river from Radnor station (Sec. 18, Twp. 26, Rge. 5, W5th). There is evidence that a small amount of this material has been removed. This was reportedly trucked to Calgary where it was cut and polished, and sold as travertine. However, a surface examination of the deposit shows little evidence that any of the material approaches travertine grade. A chemical analysis of this tufa shows about 95% $CaCO_3$, 3% $MgCO_3$, and the remainder, impurities. The deposit has a maximum thickness of about 10 feet and a length of about 200 feet along the river bank.

The remaining two deposits, one on a small creek flowing into Big Hill Creek (Lsd. 7, Sec. 10, Twp. 26, Rge. 4, W5th), and the other on the east bank of Ghost River (Lsd. 16, Sec. 33, Twp. 26, Rge. 6, W5th), are both very small.

BUILDING STONE

In the Cochrane district Paskapoo sandstone was quarried extensively for many years, mostly prior to 1915, for use as a building stone. Many of the older important buildings in Alberta were built of this stone. In the Cochrane area, quarries were operated at Glenbow and on Big Hill Creek.

At Glenbow, well jointed, yellowish-grey stone was quarried from heavy layers of sandstone, exposed near the top of the north side of the Bow River valley (NW¼, Sec. 28, Twp. 25, Rge. 3, W5th). An inclined tramway was used to move the stone to the railway in the bottom of the valley. Building stone from this quarry was used to some extent in the construction of the Legislative Assembly buildings and Athabaska Hall in Edmonton.

On Big Hill Creek, northeast of Cochrane, nearly flat lying sandstone is well exposed at many points along the northwest side of the valley. At least six abandoned quarries may be seen in Secs. 10, 11, 12 and 13, Twp. 26, Rge. 4, W5th.

In general, two sets of well defined joints may be seen in these exposures. The joints are spaced widely enough to permit the quarrying of good sized blocks. Localized hard areas are present in the beds where mineralizing solutions have concentrated cementing materials. In all cases the desirable stone is replaced by hard stone at moderate depth. Some of the Cochrane quarries were worked as late as 1935. Stone from these quarries may be seen in the west wing of the Canadian Pacific Railway Company's station in Calgary.

Although the Paskapoo sandstone was easily worked and has proven durable, it possesses many disadvantages as a building material. When laid with the bedding vertical, exfoliation results. Examples of this may be seen in the Canadian Pacific Railway Company's Department of Natural Resources Building in Calgary. When used for the base courses of buildings, it deteriorates due to wetting and injury from alternative cycles of freezing and thawing. The presence of mud spots in the stone, although not particularly serious, certainly limits its use to places where a rough finish is all that is desired. The stone also rapidly absorbs dirt. These properties are expressive of its origin in shallow water with strong and frequently changing currents. Irregular bedding, lenticularity, cross-bedding, and variation in grain size, may readily be seen in most quarries.

One of the most important features bearing on the economics of working the quarries was that the zone of usable stone never extended beyond a moderate depth. Only the top weathered zone, where the cementing carbonates had been partially removed, was soft enough to satisfy the demands of the trade.

From the foregoing, it can be seen that the non-metallic mineral resources of this region have been quite extensively developed during the past 50 years. This development has been in large part dependent upon the presence in the area of excellent transportation facilities, and an abundant supply of water, electrical power and low-cost fuel. Considering the industrialization that is taking place in Alberta and the new uses that are constantly being found for the non-metallic minerals, it is anticipated that there will be a greatly expanded development of these resources in the future.

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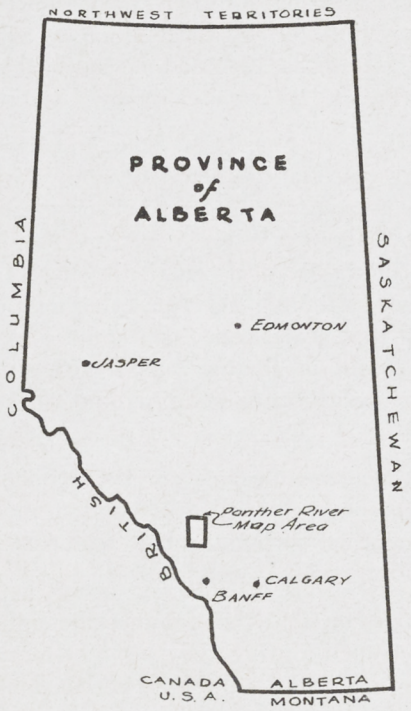
PANTHER DOME: A MINOR OROGEN OF THE CANADIAN CORDILLERA

C. WARREN HUNT[1]

INTRODUCTION

This paper describes the surface geology of an area of excellent Mesozoic and Palaeozoic outcrops at the Rocky Mountain front, some sixty miles northwest of Calgary, Alberta, Canada. The major structural units of the area are described and historically reconstructed. Palaeozoic uplift, resulting in the formation of a dome, is proven, and its effect is shown to have been later complicated and obscured by compressive Laramide structures.

INDEX MAP HERE



GEOGRAPHY

Panther Dome is situated in a large re-entrant in the Rocky Mountain front. Mountains rise abruptly to as much as nine thousand feet on three sides, southeast, southwest, and northwest. The interior of the re-entrant is made up of high, steep hills in the 5,500 to 7,500 foot altitude range. Drainage in the area is generally northeastward into the Red Deer River or its tributary, the Panther.

ACCESSIBILITY

A highway passes near the area on the east and northeast, at eight to twelve miles distance. A new road of uncertain passability has been built from the highway bridge on the Red Deer River into the map area. This latter road served the wellsite of the Union Canadian Homestead Panther River No. 12-11 well, drilled in the winter of 1955-56.

GEOMORPHOLOGY

Geomorphically the area may be divided into three regions of different prevailing land

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forms. One geomorphic region is the area underlain by marine and brackish water Upper Cretaceous strata, and lies mainly in the eastern and southern parts of the map area. It is characterized by high hills in a stage of late youth. Soils of these strata support a heavy timber cover. Land elevations range from 4,900 feet on Panther and Red Deer rivers to 6,000 feet on some hilltops.

The second geomorphic subdivision comprises the area of Lower Cretaceous, Jurassic, Triassic, and Permian outcrop. Contrasting with the land forms of Upper Cretaceous terrain, these strata support topography in a stage of early youth. Hills are higher, lack appreciable tree growth, and have a shallow soil supporting vast sub-alpine meadows ribbed with sandstone outcrops. The hilltops are commonly undulating plateaux, standing 1,500 feet or so above the dissecting valley floors. The plateaux in some cases seem to be elevated remnants of an earlier Cenozoic land surface rejuvenated by later uplift.

The third geomorphic subdivision is the typical precipitous Rocky Mountain land form, characteristic of Mississippian to Precambrian carbonate rocks. The environment comprises narrow, youthful canyons and serrate mountains, supporting little vegetation. Scrubby, coniferous growth is found scattered in sheltered situations below timberline, which is about 7,000 feet. Small meadows are found in glacial hollows or on gentle alpine dip slopes above timberline. Some of these alpine flats seem to be related to the old land surface noted on the lower Mesozoic terrain, whereas others occur by coincidence of weatherability and gentle formation dip.

Evidence that there were once substantial valley glaciers is found in the Red Deer and Panther valleys, and sign of lesser glaciation is found in cirques of the front range and scattered other localities of the map area. Some restriction of glaciation along this part of the Rocky Mountain front may be attributed to adiabatic descent of eastward moving air with a resultant low order of precipitation.

WORK METHODS

The type of mapping carried on was primarily structural delineation. Stratigraphic lithofacies were studied to assist in recognition of structure, and stratigraphic thickness and age were studied as a means to historical analysis and depth projection.

Mapping was done on aerial photographs of the approximate scale, 1.8 inches=1 mile. This data was transferred subsequently to photogrammetric base maps. Measurements were made by pace, Brunton compass triangulation, and Paulin altimeter. Locations of such calculations are shown on the map.

STRUCTURE

The map area is easily divided into several large structural units. The central unit, Panther dome, being the most interesting economically, has had the most attention focussed on it. Mapping of other units has been occasioned by need for explanation of the origin and structural setting of the dome.

In addition to Panther dome the area can be divided into three other principal units. These are: (1) Dormer Fault block, comprising Palaeozoic and Mesozoic rocks faulted over Panther dome from the northwest and west, (2) Devil's Head overthrust block, comprising Palaeozoic beds overriding from southwestward, and (3) a large undisturbed area of upper Cretaceous strata, which for reference purposes may be called the Burnt Timber syncline, to the east and northeast.

Inasmuch as the principal dips, directions of trend, and locations of important structural units are set forth by the map and cross-section, the reader is asked to study these before proceeding.

At first glance Panther dome might be mistaken for an anticline of tectonic origin. Viewing the area from a nearby mountain one sees an anticline some twelve miles long and five miles broad, aligned parallel to the principal axis of compression of the Rocky Mountains. Its east flank is seen to be overturned and thrust-faulted. Far to the south, Cambrian strata, lying on the McConnell thrust sheet, arch over the upper Cretaceous strata on the south plunge of the "anticline". On such a perfunctory inspection it seems quite clear that the entire area was once overridden by the hanging wall of the low-angle McConnell fault or Devil's Head block. It appears that the anticlinal folding was syngenetic. However, further inspection reveals some difficulties attendant upon this theory.

BURNT TIMBER SYNCLINE

First requiring explanation is the Burnt Timber syncline, a large area of gently tilted to level Upper Cretaceous Belly River strata. This syncline, contrary to the connotations of the term, is not primarily a tectonic downfold but is, rather, an undisturbed remnant of the Alberta geosyncline. Its elevation above sea level indicates uplift of at least 10,000 feet from its late Cretaceous despositional position. In the uplift, however, it has remained almost totally unaffected by Laramide compression. To be explained by structural analysis of the area is the question of how the Burnt Timber syncline could remain undisturbed while an anticline with more than 10,000 feet of amplitude formed beside it.

PANTHER DOME

Looking farther, one notes northwestward plunge of the Panther "anticline", of equivalent magnitude to its transverse closure. What tectonic force might create a 10,000 foot structural plunge in the tensile direction equal to the compressional amplitude of the structure, and that in a distance of less than three miles down plunge from the anticlinal culmination?

A critical look at the faulting on the east flank also reveals features requiring explanation. Some 2,500 feet of strata (Kootenay, Blairmore) have been overridden by east flank overthrusting, their outcrop edges now being covered as a result of faulting. Total fault displacement is in the neighbourhood of 6,000 feet, horizontal and vertical movement both being about 4,000 feet. The total structural amplitude being 10,000 feet or more, one is compelled to note how small is this nappe in comparison to the whole structure: it is disproportionately small for a structure generated wholly by horizontal compression.

A solution to these apparent anomalies is that horizontal compression did not originate the Panther "anticline". Rather, as geometry indicates, this structure is *primarily a dome,* created originally by vertical uplift. Such a dome might well have rapid plunge and enormous closure. It could have been raised by deep-seated welling with basement faulting, and in rising need not have disturbed flat lying strata in Burnt Timber syncline. Such a dome during uplift could have been modified by compression to give the overturning and overthrusting present on the east flank of the Panther structure as found today.

The setting of Panther dome in a re-entrant of the Rocky Mountain front is locally prominent. Its vertical position is nearly 20,000 feet above its late Cretaceous basinal position. Its origin, unlike the nearby overthrust fault blocks, resulted largely from upward movement. The resultant structure is a discrete block, a minor orogen of the gross cordilleran fabric.

DEVIL'S HEAD OVERTHRUST BLOCK

With the domal concept of the Panther structure the McConnell fault (Devil's Head overthrust block) is anomalous. The large Devil's Head block of Palaeozoic rocks rode eastward on the McConnell fault, covering at least part and possibly all of Panther dome. Strata above the fault are approximately parallel to it and are presently in attitudes which *simulate* those of

PLATE 1



I

Terrain of the Palaeozoic in distant view of Dormer overthrust block; Upper Cretaceous terrain in foreground.



II

View northward showing apex of Panther Dome with Rundle limestone exposed. Rocky Mountain quartzite passes behind poplars in upper right corner.



III

View southward showing overturned and overthrust east flank of Panther Dome. Note typical lower Mesozoic terrain on far right contrasting with upper Cretaceous terrain on left and in center.

the underlying Belly River beds. Thus, the eroded parts of Devil's Head Block in a northward direction rested on progressively older Mesozoic strata.

The present similarity of attitude of strata above and below the McConnell fault may be considered indicative of recurrent folding subsequent to faulting. By this process the overriding block could have been gently folded in simulation of the dome. Recurrent folding cannot, however, be proven, as it remains possible that the McConnell fault itself simulated the structure at the time of its movement, thereby leaving the overthrust strata in an attitude similar to that of the underlying structure.

DORMER FAULT

Another problem requiring historical explanation is that of the relationship of the Dormer fault block to the dome and the McConnell fault. Three factors attract attention : (1) the relatively high angle of the Dormer fault in comparison with that of the McConnell fault, (2) the crossing by the Dormer fault of the trend of the major axis of Panther dome, and (3) the resolution of the Dormer fault at depth.

Dip measurements on the Dormer fault give approximate values of 24 to 32 degrees northwestward or westward. These fault attitudes and also bedding attitudes in the hanging wall, (i.e., lack of anticlinal folding in the Dormer block), suggest genetic independence of the upthrust block from the subjacent dome. The Dormer fault at its area of maximum throw, near the northeast corner of the map area, has a vertical displacement of some two to three miles and a nearly due eastward displacement of somewhat less than two miles. Tracing the Dormer fault south one may note that a substantial fault intersects the McConnell fault west of the Devil's Head block. (Plate 3, Photo VI). This may reasonably be considered the southward continuation of the Dormer fault which, by reason of its steep dip and its intersection of the McConnell fault, appears to have originated at a later date, and by differential uplift with some compression, as opposed to compression alone for the McConnell fault. The Dormer fault seems to be dying out southward. Its displacement of the McConnell fault, if this displacement is correctly correlated with the Dormer fault, is only 1,200 feet. Thus, displacement on the Dormer fault is in marked contrast to that of the McConnell fault, the Devil's Head overthrust block having moved northeastward at least five miles and possibly much more. Vertical displacement of the McConnell fault and its position of basement intersection are obscured in the structural complex west of the map area.

Pursuant to the problem of the relationship between the Dormer overthrust block and Panther dome, magnetometer work was carried out for the purpose of basement depth determination on both sides of the fault. Results indicate a 10,000 to 15,000 foot rise in igneous basement depth across the fault, and a rapid steepening of the fault itself beneath ground surface.

The nature of the Dormer fault is ,thus, suggested by surface geology and established by magnetics to be quite different from that of the McConnell fault. It seems to be a high angle reverse fault whereas the McConnell fault is a low angle overthrust.

The above conclusion on the origin and displacement of the Dormer fault are quite contrary to existing opinion (Henderson and North, 1954), which favors its being a sole fault with large horizontal displacement. It is the writer's intention to advance here the idea that the Dormer overthrust block is a sort of "forward" range situated east from the "main" front range of the Rockies. The evidence is that it originated locally with upward and to a lesser degree outward (horizontal) movement. These characteristics clearly differentiate it from the McConnell fault, which is the main frontal fault of the Rocky Mountains in the Bow River Valley and at the south end of the Panther dome map area. Furthermore, the Dormer fault is younger than the extensive low angle overthrusts such as the McConnell represents.

STRATIGRAPHY

Era	Period	Epoch	Group	Formation	Map Symbol	Lithology	Thickness in Feet	Thickness Determined by
CENOZOIC	Quaternary		Glacial till and Fluvial terraces		Ignored in mapping	Unsorted boulder till Gravel and boulder terraces	0 TO 200	Estimation
CENOZOIC	Tertiary		Perched Fluvial terraces		Ignored in mapping	Sorted cross-bedded unconsolidated buff sands	0 TO 50	Estimation
MESOZOIC	Cretaceous	Upper	Montana	Belly River Formation	Kbr	Interbedded sandstones and shales. Shales are green to grey, soft, silty, sandy, micaceous. Sandstones are generally brown to green, fine to coarse-grained, angular, quartzose, micaceous, cross-bedded and either thinly or thickly bedded, lenticular, fairly well sorted, comprise 40 to 50% of total formation.	4000 TO 5000 (Top eroded)	Estimation
			Colorado	Wapiabi Shale	Kw	Medium to dark grey, soft, very thinly bedded shale with scattered thin sandstone beds, ironstone concretions. Some prominent sandstones occur in southern part of map area. These resemble under-lying Cardium.	2200	Measured by Union Oil Co. Checked by mapped thickness Sheep Creek
				Cardium Sandstone	Kc	Sandstone and conglomerate, fine-grained to pebble conglomerate, locally is white and quartzitic but more often is brownish-grey due to abundant ferromagnesian grains.		Measured by Union Oil Co. Sheep Creek
								Mapped thickness, upper Burnt Timber Creek.
				Blackstone Shale	Kbl	Black shale, soft, fissile, with few ironstone concretions.	800	Measured by Union Oil Co. Sheep Creek
		Lower	Blairmore Formation		Kbm	Interbedded sandstones and shales. Shales are green, grey, black or occasionally red, coaly, sandy, interbedded with thin coal measures. Sandstones are green, brown, or grey, glauconitic, felspathic, clayey, carbonaceous, have fair to poor sorting, local thick lenticular beds of pebble conglomerate, other bedding thin or medium-thick.	2650	Mapped thickness Sheep Creek
			Kootenay Formation		J-Kk	Interbedded sandstones and shales. Shales are black or dark brown, very coaly and with interbedded coal. Sandstones are clean quartzose, fine to medium-grained, brown to light grey, hard, locally with thick beds of pebble conglomerate. Extreme lateral thickness variations.	600	Measured thickness Sheep Creek
							3371	Mapped thickness on Panther River
	Jurassic	Upper	Fernie Shale		Jf	Black shale with ironstone concretions. Shale is soft, bituminous, jet black.	650	Mapped thickness Sheep Creek
	Triassic	Middle	Spray River	Whitehorse Limestone	Trw	Limestone, earthy, silty, sandy grading to siltstone and sandstone, white, pale grey or pale brown, thinly bedded, fossiliferous, with interbedded shales, weathers reddish brown, very resistant to erosion.	466	Measured thickness Dormer River
							101	Measured thickness Sheep Creek
		Lower		Sulphur Mountain Siltstone	Trs	Siltstone, thinly bedded, reddish brown, quartzitic, locally calcareous, siliceous, hard, has characteristic rippled bedding surfaces, locally grades to sandstone or limestone, often found under waterfalls caused by more resistant Whitehorse strata	381	Measured thickness Dormer River
							288	Measured thickness Sheep Creek
PALEOZOIC	Permian		Rocky Mountain Quartzite		Prm	White or light green quartzite, grey, green, red, or brown chertzite breccia, interbedded light green shales and limestones. Quartzites commonly overlie the chertzites and represent depositional Permian over post-Mississippian regolith.	200	Measured thickness Dormer River
							210	Measured thickness Sheep Creek
	Mississippian	Chester	Rundle	Mt. Head Formation	Mr	Limestone, grey to black, siliceous, hard, thin to heavy-bedded, locally silty and with thin shale interbeds or bands of sand grains or pebbles. Biostromal units with preserved corals, crinoids and brachiopods are locally well developed in the Livingstone equivalent.	1467	Measured thickness Panther River
		Meramac Osage		Livingstone Formation			1145	Measured thickness Union Canadian Homestead Panther River #12-11 (corrected)
		Kinderhook	Banff Formation		Mb	Limestone, very shaly, very thin-bedded, medium brown, platy, with some black bituminous biostromal limestone beds near top, a 10-20' silty bed locally developed near base.	630 634	Measured thickness Panther River Measured thickness U.C.H.P.R.#12-11 (corrected)
			Exshaw Formation			Black shale with some detrital material included	30	Measured thickness U.C.H.P.R.#12-11 (corrected)
	Devonian	Upper	Wabamun	Palliser Formation	Dp	Dolomite and limestone, blue, black to grey, massive to medium bedded, commonly fine to crypto-crystalline, locally coarse-crystalline, with small "patches" of chert, rare shale interbeds, local rare porosity, solution breccia in one zone near top due probably to leaching of anhydrite.	752	Measured thickness Panther River
							780	Measured thickness U.C.H.P.R.#12-11 (corrected)
			Fairholme	Nisku-Upper Ireton Equivalent	Df	Biostromal light brown, porous, coarse-crystalline dolomite overlying green calcareous shale.	58	Measured thickness Dormer fault block
				White Reef		Dolomite, white or grey, coarse-crystalline, porous, locally bedded, bichermal and bioclastic.	572	Measured thickness Dormer fault block
				Black Reef		Dolomite, black to light brown, bedded, bituminous, mainly fine-crystalline, locally porous, hard, locally bichermal, highly fossiliferous.	524	Measured thickness Dormer fault block
				Beaverhill Lake Equivalent		Dolomite, dark to light grey, thin to medium bedded, coarsely crystalline, locally fragmental, has thin basal breccia of limestone fragments.	248	Measured thickness Dormer fault block
		Middle	Ghost River Formation		Dgr	Quartzite, conglomerate, chertzite, limestone, siltshale, arenaceous oolite, cross-bedded, white or brown with pink or green tint.	205	Measured thickness Panther River
						Limestone, dark brown, silty, thin-bedded, grading down into thicker bedded white and brown, locally porous, siliceous limestone with sugary or marbled appearance.	145	Measured thickness Dormer fault block
	Cambrian	Upper?			€	Dolomite, dark grey to black, calcareous, locally sandy, thin to massively bedded, cliff forming.	Not measured	





IV



Opposite views from same point.

Southeast showing Devil's Head overthrust block on the right skyline. Lower Cretaceous subalpine grassland in left foreground.

Northward showing Dormer overthrust block over plunge of major axis of Panther Dome.

V

STRATIGRAPHIC CONSIDERATIONS

Turning now to stratigraphic information we find confirmation of the ancient dome hypothesis for the Panther structure, and some indication of the time of initial uplift and later events.

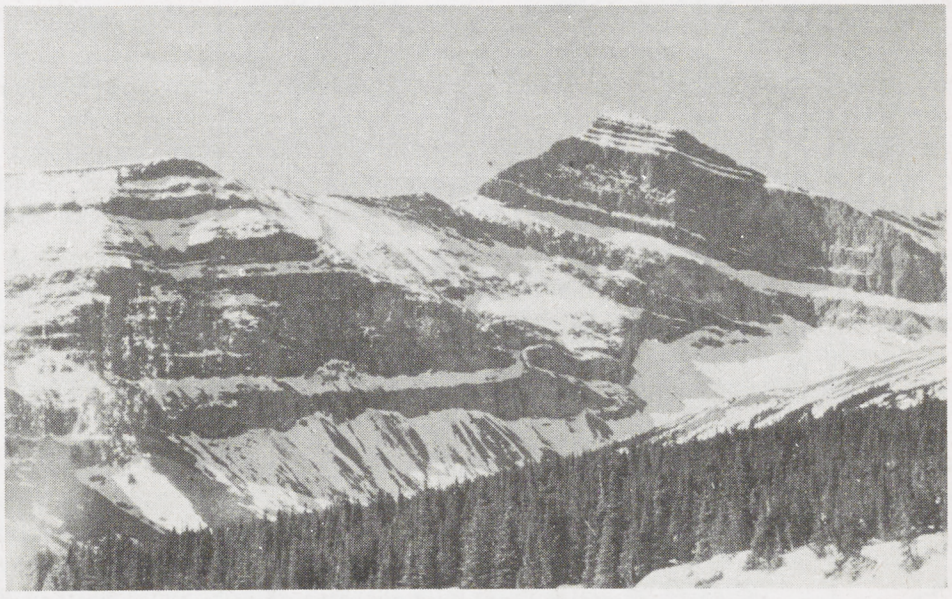
Having established by magnetometer study that the Dormer fault steepens and intersects basement rock, we have also established by corollary that rocks presently located in the isocline north of Panther dome have not been far removed horizontally from their depositional localities, at least not far with respect to strata outcropping near the apex of the dome. Hence, appreciable thinning from the point of measurement near the apex to a point of measurement on the Dormer isocline may be considered evidence for the existence of the dome either at the time of deposition or subsequent to deposition and prior to a post-depositional erosion period.

Formations which thin appreciably between the Dormer isocline and Panther dome are: Ghost River (?), Rundle, Spray River (both members), and Kootenay.

The Ghost River formation is not confirmed in the Union Canadian Homestead Panther River No. 12-11 well. If present at all, it is thin and its base has been cut off by a fault. No clear support of the idea of uplift during or prior to Ghost River deposition is given by this formation. It may be noted in passing that some evidence for erosional unconformity between Cambrian and Ghost River strata exists in this locality. A carbonate conglomerate present northeast from the structure rests in erosion pockets in the Cambrian limestones. This conglomerate is absent near the structural apex.

Upward in the section there is no apparent thinning of Upper Devonian or Kinderhookian strata. The later Mississippian Rundle formation, however, is definitely thinned 300 feet by erosion at the apex of the dome. Overlying the Rundle limestone the Permian Rocky Mountain quartzite has a normal thickness. Uplift may be considered, therefore, to have occurred in the post-Mississippian Culmide revolution.

PLATE 3



VI

View southwestward showing Dormer fault offsetting McConnell fault, and Cambrian strata of Devil's Head overthrust block. Displacement: 1200 feet.

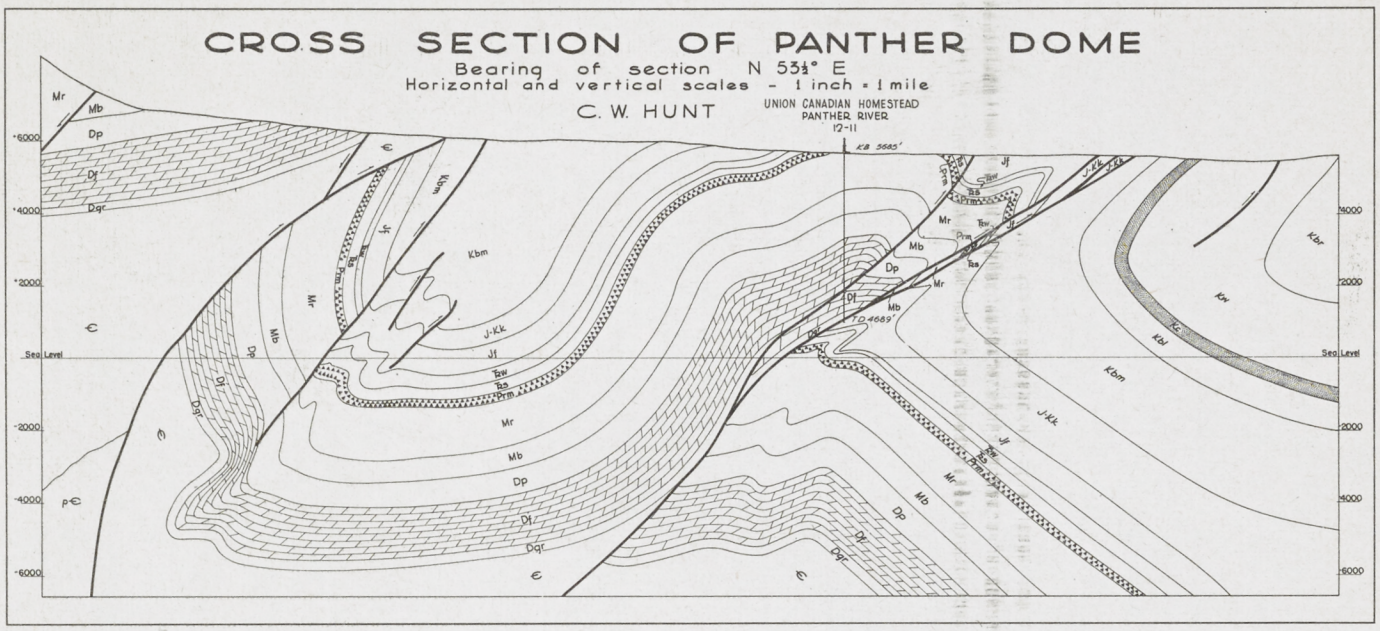
Blairmore Kbm
Jurassic Jf
Whitehorse Trw
Sulphur Mtn Trs
Rocky Mtn PRm
Rundle Mb
Banff Mb
Palliser Dp
Fairholme Df
Ghost R Dcr
Cambrian €

CROSS SECTION OF PANTHER DOME

Bearing of section N 53½° E
Horizontal and vertical scales - 1 inch = 1 mile

C. W. HUNT

UNION CANADIAN HOMESTEAD
PANTHER RIVER
12-11



The two Triassic members, Sulphur Mountain and Whitehorse, are definitely present and definitely thin. This seems to be due to minor disconformities and individual bed thinning rather than to erosion. Thinning is taken for support of Triassic uplift.

Jurassic-Lower Cretaceous Kootenay thinning is extreme and is due without reasonable doubt to bed thinning and periodic nondeposition over a submarine dome.

RESUME

In summary, therefore, it may be said that domal uplift has not been shown to have occurred before post-Mississippian time. The Rundle is thin, and the reduced section is due to *erosion* after Culmide uplift.

It may be appropriate to point out here that domes of similar nature to Panther dome occur at Moose Mountain (Beach, 1945), fifty miles to the southeast, and at Scalp dome, (Yaha Tinda Ranch) eighteen miles northwest. Alignment of these three orogens is suggestive of deep-seated structural causes such as intrusion along a fissure.

Recurrent uplift of Panther dome after Culmide diastrophism occurred during Triassic and Jurassic times. The area, however, was not exposed to erosion after the Palaeozoic but merely remained closer to wave base, and received less sediment, while adjacent areas became markedly deeper during Triassic and Kootenay times. Uplift between Kootenay time and the Laramide revolution cannot be established because rocks of these ages have been removed by Cenozoic erosion close to the apex of the dome.

The earliest Laramide disturbance, probably at considerable depth below both sea level and sea bottom, caused low angle overthrusting from the southwest, with Cambrian rocks overriding all strata up to the Belly River; this faulting sliced an oblique section from the top of Panther dome. Concurrently with early Laramide compression the ancestral dome itself was (1) compressed, (2) overturned, (3) overthrust, and (4) uplifted, with the principal orogeny of the Cordillera. It is noteworthy that Laramide thrust faulting did not have comparable effects on Moose or Scalp domes, which were uplifted without significant compression. The occurrence of both doming and low angle overthrusting in the region of Panther dome is chance tectonic interference. It is implied from these events and the resulting geometry of the area that this orogeny raised the Rocky Mountains by uplift more than by shingle-structure overthrusting. Sheet overthrusting in the proper perspective is but one part of the mountain building process and for this locality it seems to be less of a contributor than direct vertical uplift.

As outlined above, the tectonic sequence in Laramide times was: (1) sheet overthrusting, an event that is thought to have occurred when the area was still far below sea level, (2) the entire area was raised somewhat and further compressed, (3) finally the *major uplift* at the close of the Laramide revolution occurred. This was accompanied by more uplift of the structure and by displacement on the Dormer fault. This latter movement resulted from differential uplift with some concurrent horizontal compression from the west.

Post-Laramide erosion set in after uplift and reduced the area to physiographic old age, after which minor later uplift rejuvenated the drainage and isolated some terraces on high hillsides, as well as leaving topographic remnants of the old surface out of reach of present active erosion. Pleistocene glaciers dumped considerable debris along the river courses and close to front range cirques, but had little other effect on the area.

ACKNOWLEDGMENTS

The writer is indebted to the geologists of the Union Oil Company of California for their valuable criticism and stimulating argument on points of interest and geologic contention, Mr.

Orhan Baykal and Dr. W. C. Gussow of that Company were particularly helpful, Mr. Baykal having mapped the area independently, and having first pointed out several critically important features about the structure. Palaeontological and geological assistance of value was received from Mr. L. E. Workman, Dr. C. Raasch, and Mr. Dallas Bossort of Canadian Stratigraphic Service, and from Dr. Rein de Wit of Sohio Petroleum Co.

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THE PALLISER-EXSHAW CONTACT[1]

C. H. CRICKMAY[2]

In western Canada, except in the most incomplete sections, the Devono-Mississippian boundary must necessarily be an imaginary thing; but the Palliser-Exshaw contact, though it may be elusive, and rarely seen, is at least real. No one who retains a capacity for telling the truth can say positively and definitely that here the Devonian ends, and the Mississippian begins; but the contact between typical Palliser limestone and the type Exshaw shale can be studied for what it is worth, provided we avoid saying of it positively that it *is* the Devono-Mississippian boundary. The locality where this study may be pursued is on Jura Creek which flows into the Bow Valley 1½ miles northeast of Exshaw, and is about 2 miles up that stream from the highway. The place to which this description leads is, of course, the type section of the Exshaw shale, named by Warren (1937).

There is probably nothing in exploration literature less satisfactory than the descriptions of those difficult entities, the sedimentary contacts. Either they are not described at all or they are depicted merely and unqualifiedly as unconformities. Unfortunately, that term has been redefined, classified and abused so much by good-intentioned evil-doers that at this date it means little and has almost become part of the familiar jargon of geological sciolism. The westwardly dipping Palliser-Exshaw contact on Jura Creek has fared better than some. Warren (1937) described it accurately as sharp, and interpreted it as an unconformity. The writer has seen nothing else in print that really bears on it, though there is much, no doubt, in private notebooks and confidential files. However, it is not difficult to add something to that which is already published.

In the first place, the contact is not only sharp, it is also approximately plane in any one outcrop; there are no large-scale swells or hollows on it. When viewed on edge, in any direction, it appears as a straight line. However, when examined more closely, it is seen to be marked by a few small pits and low protuberances an inch or more across. In the outcrop, these are the only discernible irregularities in that remarkably flat interface. Other writers, for instance de Wit and McLaren (1950), ascribe the same characteristics to this contact at other places. No one has reported channeling or cutting, or any evidence of the Palliser surface having been eroded.

In the second place, the bedding in the limestone below, as in the shale above, is parallel with the contact. That this is not an accidental or merely local characteristic may be determined by following the contact farther up the valley. No change in the condition is to be found. Verification may be pursued to other localities for greater assurance; for instance, a locality 3 miles west-southwest of Canmore and half a mile northwest of the pass through the Rundle Range where at elevation 6,000 feet, the Exshaw and Palliser, both well exposed, lie in contact and in virtually perfect parallelism. Another locality showing the same relationships is that at 6,900 feet on the south slope of Mt. Standly overlooking Lake Minnewanka. With the testimony of these other outcrops supporting the interpretation made herein of the relationships on Jura Creek, it seems safe to interpret the contacts as totally free from discordance.

The topmost beds of the Palliser formation on Jura Creek are well, though not very obviously stratified, somewhat dark grey limestones containing the following and other fossils:

Strophopleura raymondi Haynes
Choristites cf. glennfoxi Crickmay
Cleiothyridina cf. humerosa Stainbrook

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[2] Geologist, Imperial Oil Ltd., Calgary, Alberta.

At eight feet below the contact, these species have disappeared; their places are taken by: *Cyrtiopsis* cf. *monticola* Haynes and others. A similar disappearance of the uppermost Palliser fossils occur at other localities as the collector probes more than five to ten feet into the formation. With the aid particularly of the highly recognizable *Strophopleura raymondi,* this phenomenon may be traced through the subsurface. In Imperial Youngstown No. 1, (Sec. 3, Twp. 30, Rge. 9, W4th), S *raymondi* is confined to the three feet of limestone immediately below the Exshaw shale. No such relation can be found in the Leduc oilfield area because the Exshaw is not there, and the top of the Devonian is a lower horizon than that which we have so far found at our contact (the highest Palaeozic in Imperial Leduc No. 2 being 30 feet of upper Banff limestone lying on the eroded Wabamun surface). However, in Imperial Normandville No. 1 (Sec. 16, Twp. 79, Rge. 22, W5th), S. *raymondi* and *Choristites protistus* Crickmay occur through the uppermost ten feet of limestone below the Exshaw. These occurrences seem to show that, at many, widely separate places, the limestone bed immediately below the Exshaw contact is one and the same bed.

From that another conclusion may be derived. Since it is highly unlikely that erosion could denude the Palliser limestone to perfect flatness and to the identical bed in different places, it is probable that no measurable quantity of erosion of the original Palliser top occurred prior to the deposition of the Exshaw.

The basal bed of the Exshaw on Jura Creek consists of 3 inches of pyritic and slightly phosphatic, black claystone, some of which is minutely rubbly. This is overlain by the beds described as:

Dark grey, friable shale with *Allorisma* sp. throughout, *Aganides* cf. *discoidalis* Smith in the upermost 6″	10 ft.
Black, papery, unfossiliferous shale with a few, large, pyritic concretions	9 ft.
Tough, silty, dark grey shale, weathering an earthy grey	5 ft.
Black, papery, bituminous shale	7 ft.

lying upon 3inch basal bed which lies on the Palliser limestone.

This section, overlain by basal, dark grey, silty, calcareous shales of Banff formation changes as the Exshaw is followed from place to place. Above all else, thickness varies. Neighboring mountain sections may be as thin as 20 feet or as thick as 35. The Youngstown No. 1 section is 1 foot thick; the Normandville, 10 feet. All the occurrences are similar in being exceedingly fine-grained in the main, very black, somewhat bituminous.

At present it would be impossible to prove either that the Exshaw represents any considerable lapse of time or that it includes even a small gap in its continuity of sedimentation. These notions suggest also the possibility of evaluating chronologically the Palliser-Exshaw contact. Enough has been said to indicate that if the contact marks by its sharpness, as seems likely, an hiatus in the record, that hiatus must be expected to be a very small one.

The fossils in the uppermost Palliser (we should perhaps say uppermost bed of the Costigan member) are to be correlated with the top bed of the Three Forks formation of southwest Montana (not including the thin black shale which separates Three Forks from Sappington Sandstone and which might well be termed Exshaw if the Montana geologists could be induced to adopt an Alberta name), with the Aplington of Iowa, and with the Ouray and Percha of Colorado and New Mexico. These have at one time or another been regarded as latest Devonian or earliest Mississippian. There is no consistency in these opinions, nor have they been based on indisputable criteria. In view of the requirement existing nowadays of these things having to be reported very often by people who know little about them to people who know even less, it is at worst a worthwhile simplification to regard the top of the Costigan member, *provided it is overlain by Exshaw,* as the top of the Devonian System. The writer's (1952) suggestion that some of the Costigan fossils have Mississippian relationships has been overzealously and mistakenly interpreted by some to mean that a Mississippian correlation is positively indicated. The original suggestion was neither definite nor positive. Such forms as

Choristites protistus or *Ch. glennfoxi*, though they resemble greatly the Mississippian species, may be no more than the late Devonian ancestors of *Choristites*.

The fossils in the upper part of the Exshaw are familiar Mississippian forms. The pelecypods appear at various places in the overlying Banff formation along with Kinderhook species of *Spirifer* such as *louisianensis*. The ammonoid, formerly identified with a Devonian form, which, in the writer's opinion, it resembles much less than it does the early Mississippian *Aganides discoidalis*, does not, unfortunately, declare any too plainly its relationships or its chronologic position. And as for the lower beds of the Exshaw, except for subsurface stations, we are lacking palaeontological evidence.

A sound suggestion, lately repeated by H. Belyea (1955), is that because of its kind of sedimentary material, the Exshaw may be taken to mark the beginning of Mississippian sedimentation. In view of its having been seperated from the Banff and distinguished by a name *only* because it was once thought to be of Devonian age, we might well now regard the Exshaw as a basal member of the Banff formation. This, though it brings us no nearer the solution of the ultimate correlation problem, provides a basis for work within the basin which is likely to be acceptable and which will promote local scientific progress.

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STRUCTURAL CONDITIONS IN COAL MINES OF THE CANMORE AREA, ALBERTA[1]

D. K. NORRIS[2]

INTRODUCTION

In order that criteria might be established to assist the coal mining industry in safe and economical deep mining practices, the author, in co-operation with officers of the Mines Branch, Department of Mines and Technical Surveys, made a detailed study of structural conditions in coal mines of the Canadian Cordillera and in certain eastern Canadian coalfields.

In the eastern Cordilleran region, underground studies were carried out in the Fernie, Crowsnest, Cascade and Nordegg coal areas. It is the purpose of this paper to interpret the deformation of the Kootenay formation in the Cascade coal area, as revealed from structural features encountered in the active workings of certain seams being mined by Canmore Mines Limited at Canmore, Alberta.

The coals of the Cascade area are unique in that they are the only low volatile bituminous and semianthracite coals being mined in commercial quantities in Canada at the present time. Their high calorific value (13,500 to 14,000 B.T.U. per pound), and in many instances their blocky nature, has particular appeal to the domestic market.

STRATIGRAPHY

THE KOOTENAY FORMATION

Outcrops of Kootenay strata are sparse below tree line except possibly in creek bottoms, because of the predominance of shales in the lower part of the formation. On ridge tops and above timber line, however, exposures are good. From his cross-sections of the Canmore area, MacKay (1935) has indicated the thickness of the Kootenay formation to range from 3,100 to 3,300 feet. There is, however, an undetermined thickening by back-limb thrust faults on the east flank of the Mount Allan syncline. In the Ribbon Creek area, along strike to the south-east, Crockford (1949) determined the formation to be 3,400 feet thick.

In order of decreasing abundance, the predominant rock types in the Kootenay formation at Canmore are: dark grey to black, silty shales; fine to coarse grained, cross-bedded, rusty brown weathering sandstones; dark grey to black, thin bedded siltstones; black, carbonaceous shales and chert and quartzite pebble-conglomerates. There are at least 12 coal seams of commercial interest, of which no less than 5 either have been or are being mined. The seams occur for the most part as interbeds in shales of the lower third of the formation. Difficulty in correlating seams encountered in cross-measure tunnels at various points along strike in the Kootenay formation suggests that many of the seams may pinch out along strike, and that few seams are continuous throughout the Canmore area.

On the basis of gross lithologies the Kootenay formation may be divided into four units (Crockford, op. cit.). Marking the base of the formation is a persistent coarse grained, dark grey to black sandstone member, ranging in thickness from 50 to 75 feet. Overlying this is a coal bearing shale member making up about one-third the thickness of the formation. Coarser clastic rocks predominate in the upper two-thirds of Kootenay strata, with thick bedded, fine to medium grained sandstones of the upper sandstone member being overlain by a four hundred foot member composed largely of interbedded coarse grained sandstones, and chert and quartzite pebble-conglomerates. The conglomerate and upper sandstone members appear to be the

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[2] Geologist, Geological Survey of Canada.

equivalent of the Upper Part of the Kootenay formation in the Mount Head area (Douglas, 1950) sixty miles to the southeast.

In the Canmore area the base of the Kootenay formation is marked by a distinct color change from the dark grey to black of its basal sandstone to the light grey and brown weathering of the sandstones at the top of the Passage Beds of the Fernie group. The contact with the Blairmore group is drawn at the base of the first thickly bedded to massive, chert and quartzite pebble-conglomerate.

REGIONAL STRUCTURE

The Cascade coal area is included in the Lac des Arcs thrust sheet (Clark, 1949). To the west it is limited by the Rundle fault, along which Cambrian and Devonian formations have been thrust over the coal bearing Kootenay strata. Repetitions within Devonian and Mississippian strata, evident in the majestic peaks of the Three Sisters at Canmore, are due to three splays from the Rundle fault.

The Kootenay formation is folded into a prominent, asymmetrical syncline, the Mount Allan syncline, which extends throughout the length of the Ribbon Creek area, immediately to the southeast (Crockford, op. cit.), and an unknown distance to the northwest along the front of the Rundle range. At the base of the Three Sisters upper Kootenay beds exposed on the west flank of the syncline are vertical to overturned, whereas those on the east flank dip west at 10 to 20 degrees.

Partly covered by the Pleistocene and Recent deposits of Bow River valley is a gently west dipping sequence of the Fernie group and Spray River formation. These latter beds outcrop low on the west flank of Fairholme Mountains, and dip at 30 to 35 degrees to the southwest. The underlying sequence of the Rocky Mountain formation and Rundle group is relatively undisturbed. High on the east flank of Grotto Mountain in Fairholme Mountains, however, a minor west dipping fault has carried Banff beds over Rundle beds, and the sequence continues through the Devonian formations into Cambrian strata. The latter are in thrust contact with Rundle strata on the Lac des Arcs fault.

STRUCTURAL FEATURES OF THE COAL SEAMS

Three coal seams were examined in detail in the Canmore area, Number 4 seam and successively below it the Upper and Lower Marsh seams. All three beds lie within a stratigraphic interval of about 200 feet, and are found some 1,200 feet above the base of the formation.

The Lower and Upper Marsh seams are much sheared, and features such as cleat and bedding have been largely destroyed by differential slippage between roofs and floors of the seams. There are abundant slickensides paralleling the dip and polish at the contacts of the coal with adjacent strata. Drag-folds within the coal consistently indicate a differential movement up the dip of the hanging-wall relative to the seam, and the seam relative to the foot-wall. There has been a tendency for successively higher beds to ride out of the axial region of the Mount Allan syncline. Because of this differential movement there is frequently no direct counterpart in the floor of faults in the roof and vice-versa.

Although all seams examined displayed similar deformational features to varying degrees, the Number 4 seam afforded the most data because of the greater extent of the workings in it (Number 4 mine). Figure 1 is a structure map of the accessible parts of the seam. In contrast to the Upper and Lower Marsh seams, and in fact all seams investigated in the Cordillera, Number 4 exhibits a remarkable cleat and fracture system, each system consisting of two sets.

Both cleat sets are perpendicular to the seam; one, striking north 30 degrees west, parallels the strike of the seam, and the other, striking south 60 degrees west, parallels the dip. Their



2. A coal tipple in the lee of the Rundle Range. The Three Sisters in the left background consist of fault repeats of Devonian and Mississippian strata. The Rundle fault underlies the Range. In the foreground is the coal-bearing Kootenay formation, largely concealed by forest cover.(Photo courtesy of the Department of Mines and Technical Surveys, Ottawa).

surfaces are characteristically bright, especially where they cross vitrain bands. That set paralleling the dip is more prominent, and results in breaking of the coal into smooth, tabular sheets as thin as one-eighth of an inch, and up to one-quarter of an inch. The counterpart of this set is generally poorly developed.

One fracture set strikes north 10 degrees east and dips 70 degrees northwest, and the other strikes north 85 degrees west and dips 70 degrees southwest. They are in general equally well developed throughout the seam, although at some points one or other set may be absent. The fracture planes are spaced on the average from one to two feet apart, and extend from roof to floor, so that the coal is cut into large rhombohedrons. Upon rotation of the seam into the horizontal the bisectrix of the acute angle between the fracture sets plunges 50 degrees northeast and strikes within 10 degrees of the perpendicular to the regional structure trend, i.e., within 10 degrees of the direction of shortening of the eastern Cordillera in the Canmore region.

The dull and minutely slickensided surfaces of the fracture sets are indicative of shear. Whereas the bright surfaced cleat sets may be a product of early and very mild deforming stresses, it is suggested that the fracture sets were developed in the coal at a slightly later and stronger stage of Laramide deformation.

The trend of faulting in Number 4 seam (Figure 1) is a few degrees west of north and cuts across the levels at an acute angle. Faulting is concentrated in the northwest section of the workings, where the seam dips from 20 to 25 degrees west; to the southeast, where the seam flattens to about 10 degrees west, faults are few.

The bottom of the main slope, Number 4 mine, was particularly amenable to a study of the time relationship of faults which offset one another. Here, as in other seams examined, there is nothing systematic, and it is concluded that all faults with a common trend were not formed simultaneously. This fact is borne out in severely sheared seams, where faults cutting roof strata are offset with respect to their counterparts in the floor, whereas other faults may be traced directly from roof to floor through the coal. In the latter instance the faults must have developed after interstratal slippage.

Of the 175 faults mapped underground in the seams at Canmore, 97 per cent were extensional features and 3 per cent contraction features. For the eastern Canadian Cordillera, 885 faults in all coal seams were examined, and of these 90 per cent were extensional (normal) and 10 per cent contraction faults. By comparison, Raasveldt's investigations (Sax, 1946,) of faulting at the Willem Sophia mine in the coal measures of the Netherlands revealed that of 2,102 observations, 21 per cent of the faults were "upthrusts" and 79 per cent were "normal" faults.

Approximately one-half of one per cent of the faults examined in coal seams of the Cordillera are perpendicular to the bedding. Their stratigraphic throws rarely exceed one foot. The scarcity of these faults emphasizes the failure of joint systems perpendicular to the bedding to act as incipient fault planes.

The maximum observed stratigraphic throws of extension (normal) faults examined in the seams at Canmore are invariably small. It was not practical to record those faults with throws less than 6 inches because of their profusion. Consistent with regional considerations, faults with throws in excess of 10 feet are scarce, whereas those with throws between six inches and two feet make up 50 per cent of all extension faults measured. Three contraction (reverse) faults examined had maximum observed throws ranging from 7 to 12 feet, although the frequency distribution for 81 such faults examined throughout the southern Canadian Cordillera showed a peak value at throws of from one to two feet, with the frequency declining more rapidly for smaller throws than for larger values (Norris, 1956).

The frequency distribution of observed dips of extension faults in Number 4 seam is presented in Figure 2a. The distribution, although irregular, is not completely random as there

is a tendency for few faults to dip less than 20 degrees. This is to be expected, however, because the seam dips within the relatively small range of from 10 to 25 degrees, and there exists a tendency for extension faults to cut the bedding at about 60 degrees.

To test the existence of a preferred angle at which extension faults cut bedding planes, the strata in the immediate vicinity of the faults examined were rotated into the horizontal and new dips of the fault planes obtained. The frequency distribution of the dips after rotation of the beds is slightly asymmetrical (Figure 2b), with a peak value at approximately 60 degrees.

Data at Canmore on contraction faults were too few to permit a similar analysis. For the eastern Canadian Cordillera, however, the frequency distribution of observed dips is irregular, with a tendency for few faults to dip less than 20 degrees. The frequency distribution of the dips after rotation of the beds into the horizontal is moderately asymmetrical with a peak value at approximately 23 degrees (Norris op. cit.).

The preferred angles at which extension and contraction faults cut the seams are roughly complementary, and are within 5 degrees of values determined by Hubbert (1951), from sand-box experiments. From theoretical considerations it may be shown that, to a first approximation in the behaviour of cohesive solids, these two angles should be complementary.

MECHANICS OF COAL SEAM DEFORMATION

Shearing and faulting in the productive measures of the Canmore area appear to be due respectively to interstratal slippage in folding, and overriding of thrust sheets.

In folding it is suggested that the Kootenay formation behaved like a laminated beam, with each lamina free to slip at its interfaces. There would then be a neutral axis corresponding to each structural unit in the formation. The friable and sheared condition of some of the seams is testimony to differential slip in the development of the Mount Allan syncline. Drag-folds in the coal, moreover, indicate that successively higher beds in the formation have overridden one another away from the axial plane of the syncline.

Irregularities in the surfaces of the faults which break the east flank of the Mount Allan syncline, and of the Lac des Arcs fault and its splay on Grotto Mountain, are believed to result in flexing of the overriding masses. Consequently a given bed or stratigraphic interval is alternately subjected to localized relaxation and compression.

Extension faults, resulting in elongation of the strata in the plane of the bedding, are due either to relaxation locally on shoulders or on the outsides of neutral axes of folds. Contraction faults, on the other hand, are due to compression, whether from lateral forces involved in movement of thrust sheets or from forces arising inside neutral axes of folds.

Although data were not forthcoming from the Canmore area, extension faults have been traced through stratigraphic intervals in excess of 100 feet with no apparent offset of the fault planes. This suggests that large intervals, in some instances involving diverse rock types, behave as structural units and undergo relaxation simultaneously. Evidence from interstratal slippage, moreover, would suggest that adjustments to compression on the insides of folds takes place at successive lithologic discontinuities.

The frequency distribution of extension faults with respect to their maximum observed stratigraphic throws implies inherent weakness of the coal measures in relaxation, with adjustment taking place on a profusion of extension faults of negligible throw and relatively few faults with throws in excess of 10 feet. In addition, the strength of strata in compression is suggested by the small population of contraction faults. According to the frequency distribution of their throws, the ability to transmit compressive forces through the strata apparently favors the development of few faults of small throw and a still smaller number of faults of either

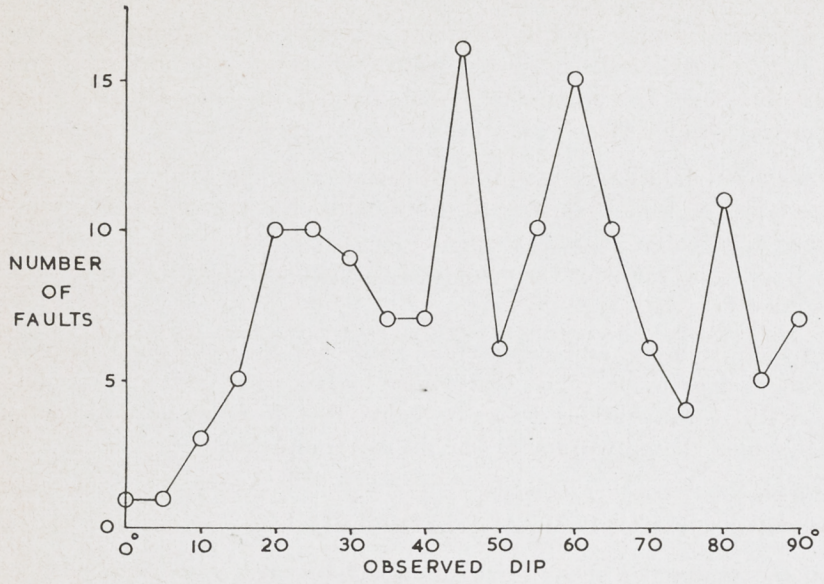


FIGURE 2A

FREQUENCY POLYGON OF OBSERVED DIPS OF EXTENSION FAULTS

NUMBER 4 SEAM
CANMORE, ALBERTA

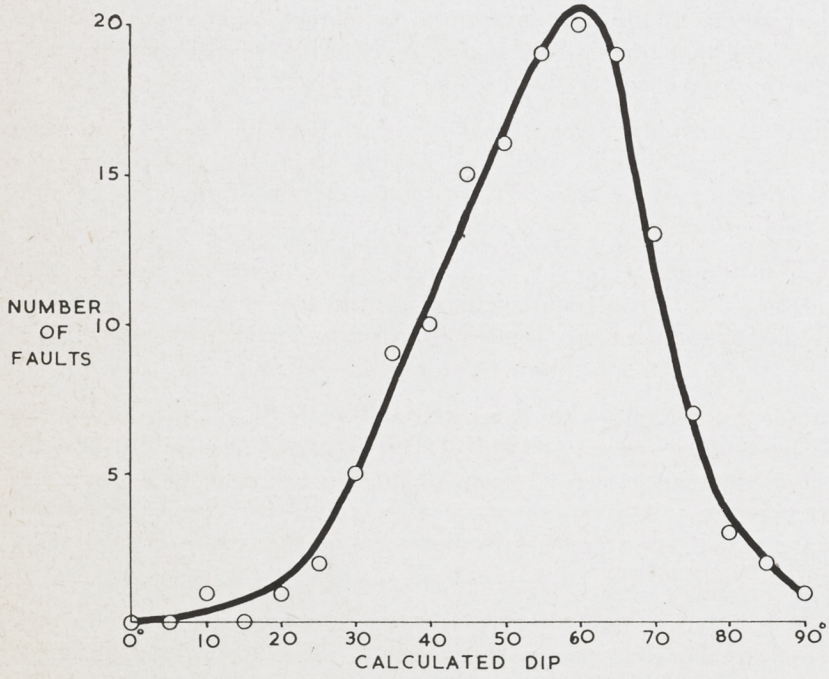


FIGURE 2B

FREQUENCY DISTRIBUTION OF CALCULATED DIPS OF EXTENSION FAULTS FOR HORIZONTAL BEDDING

NUMBER 4 SEAM
CANMORE, ALBERTA

negligible or very large throw. In regional terms, for every thrust sheet it would appear that there exist many contraction faults, with maximum observed stratigraphic throws of one to two feet.

Dispersion of the data in the frequency distribution of observed dips of extension and contraction faults referred to in the previous section, is apparently a consequence of rotation of these faults after their development and the influence of topography and bottom shear stresses on the disposition of the principal stress axis.

That there is a preferred angle at which extension faults cut the bedding is consistent with the major principal stress axis being about perpendicular to the bedding when the strata are being elongated; in compression the major principal stress axis is about parallel to the bedding. The skewness of the curves may be due to inadequate sampling and/or tilting of the principal stress axes with respect to the bedding during overriding of thrust sheets.

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DEVONIAN SEDIMENTS OF BOW VALLEY and ADJACENT AREAS[1]

HELEN R. BELYEA[2] and D. J. McLAREN[2]

INTRODUCTION

Excellent exposures of Devonian sediments outcrop in the mountain ranges cut by Bow River Valley. These are particularly important in that they are among the most readily accessible sections of the Devonian strata that produce oil in the Alberta Plains.

Three major subdivisions of the Devonian in Bow Valley may be readily recognised; from the top down they are the Palliser and Alexo formations and Fairholme group. Each may be recognized by its distinctive physiographic expression (Plate IA). The upper part, the Palliser formation, forms a light grey, massive cliff under the brown weathering Banff shales. The Palliser rests on the Alexo formation, which forms a relatively gentle slope commonly covered with talus and vegetation and weathering to a yellowish brown colour. This is underlain by the Fairholme carbonate sequence, the upper part of which is banded light and dark grey, the lower part, dark grey. It weathers to a relatively gentle slope with numerous cliff-forming layers. The Fairholme rests on ochre weathering sub-Devonian beds.

In Bow Valley the exposed Devonian sequence is predominantly carbonate. This carbonate sequence changes laterally to varying facies with the result that correlation is difficult and formational nomenclature becomes complicated. This is patricularly true of the Fairholme group in which equivalent clastic, carbonate, and evaporite sequences occur in central and southern Alberta in both mountains and plains. In this paper an attempt has been made to eliminate much detail and show the general pattern of correlation and facies changes of the Fairholme group within the framework of a practical nomenclature. Within this framework the carbonates of Bow Valley are related to the clastic sequence of North Saskatchewan and North Ram River areas in the mountains and to the similar sequence of the Central Alberta Plains.

Hitherto the rock terminologies of the surface and subsurface in Alberta have been kept strictly separate, although names from as far away as central Montana have been imported into south central Alberta. The subsurface rock terminology erected by Imperial Oil Limited (1950) for the vicinity of Leduc oil field has been successively extended so far southward and eastward that, in some cases, correlation of rock units bearing the same names is, at the least, unproven and possibly unreliable.

Belyea (1956a and in press) has erected a self-consistent classification for the Southern Alberta Plains employing in part Leduc area names, e.g. Cooking Lake, in part names proposed by Wonfor and Andrichuk (1953), e.g. Stettler formation, and in part informal descriptive names, e.g. stromatoporoidal limestone facies. In outcrop, in Bow Valley, McLaren (1956) has recently divided the Devonian sequence into a number of informal descriptive members, varying from place to place and grouped into new or existing formations.

The present report essays to combine the rock unit classifications employed by Belyea and McLaren, thus emphasizing the close similarities between the surface and subsurface sequences in the area under consideration. These similarities apply not only to individual sections or wells, but also to the pattern of facies changes encountered both in the mountains and in the Southern Alberta Plains.

The Cairn formation is extended to the subsurface, where its relations with the Cooking

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Lake are precisely similar to its surface relations with the Flume. To elucidate these relations and achieve a satisfactory terminology arbitrary cut-off may be employed in the subsurface where the Cooking Lake grows into the Cairn at the expense of the overlying Duvernay, to form the base on which the Southesk formation (=dolomite-evaporite unit) rests. The Cooking Lake loses its identity near the shelf margin reef complex and is not readily separable from the Cairn.

The Southesk formation is also recognizable on the shelf margin reef complex and, where practicable, Belyea's dolomite-evaporite unit and Delia formation may be separated, – again by employing arbitary cut-off. These formations bear the same relation to the Ireton in the subsurface as to the Mount Hawk formation in outcrop. The lower and upper Leduc members of the Woodbend appear to correspond to the Cairn formation and lower grey dolomite member of the Southesk formation respectively, with an Ireton tongue extending across the top.

The Alexo and Palliser formations of the mountains are also recognizable in part of the Winterburn group and the Wabamun group of the plains. Here, also, rapid changes in both facies and thicknesses from mountains to plains makes exact correlations doubtful.

It should be emphasized that the units – members and formations – employed in the charts and diagrams of this report are rock units. Similar facies types, or rocks believed to have been similar before diagenetic alteration, are grouped together. A three dimensional picture of the extent and interrelations of rock masses is the goal, and the illustrations constitute a preliminary attempt at rock correlations between two areas separated by tectonic accident.

Biostratigraphic correlation is also possible between the surface and subsurface Devonian sequences. Table I lists selected faunas from the mountains and plains, grouped according to their stratigraphic positions within formations. Faunas from the Wabamun and Winterburn groups are not shown (but see Crickmay 1952). The outcrop faunas shown are from the clastic formations of the Fairholme group, although most of the forms listed are known also from fossiliferous lenses and tongues within the carbonate sequence formations. Similarly in the subsurface, the faunas are shown for the formations of the basinal facies. The biostratigraphic classification parallels the rock classification in general, but it does not always do so in detail. Table II illustrates as far as known the relations of the surface and subsurface formations to the rhynchonellid zones of McLaren (1954).

FAIRHOLME GROUP

CAIRN FORMATION

The name Cairn formation was proposed by McLaren (1956) for the brown to black organic dolomites of the lower part of the Fairholme group. The type section is on the northern spur of Mount Dalhousie, immediately south of the Southesk and Cairn rivers junction (Plate 1B). It is divided into two members, the descriptions of which are applicable to the outcrops in Bow Valley.

"The lower, designated the cherty dolomite member, is 101 feet thick at the type section and consists of dark grey, fine- to medium-grained dolomite with nodules, bands, and stringers of chert abundant in the upper 70 feet. Some stromatoporoids occur in the top 75 feet, and *Amphipora* is abundant in bands below.

The upper or organic dolomite member is 457 feet thick at the type section, and is formed of grey to dark brownish grey to brown, medium-grained dolomites, medium- and thick-bedded to massive and slightly argillaceous, with very abundant traces of organic remains. The thicker and massive units are largely composed of spheroidal stromatoporoids with scattered *Amphipora* and

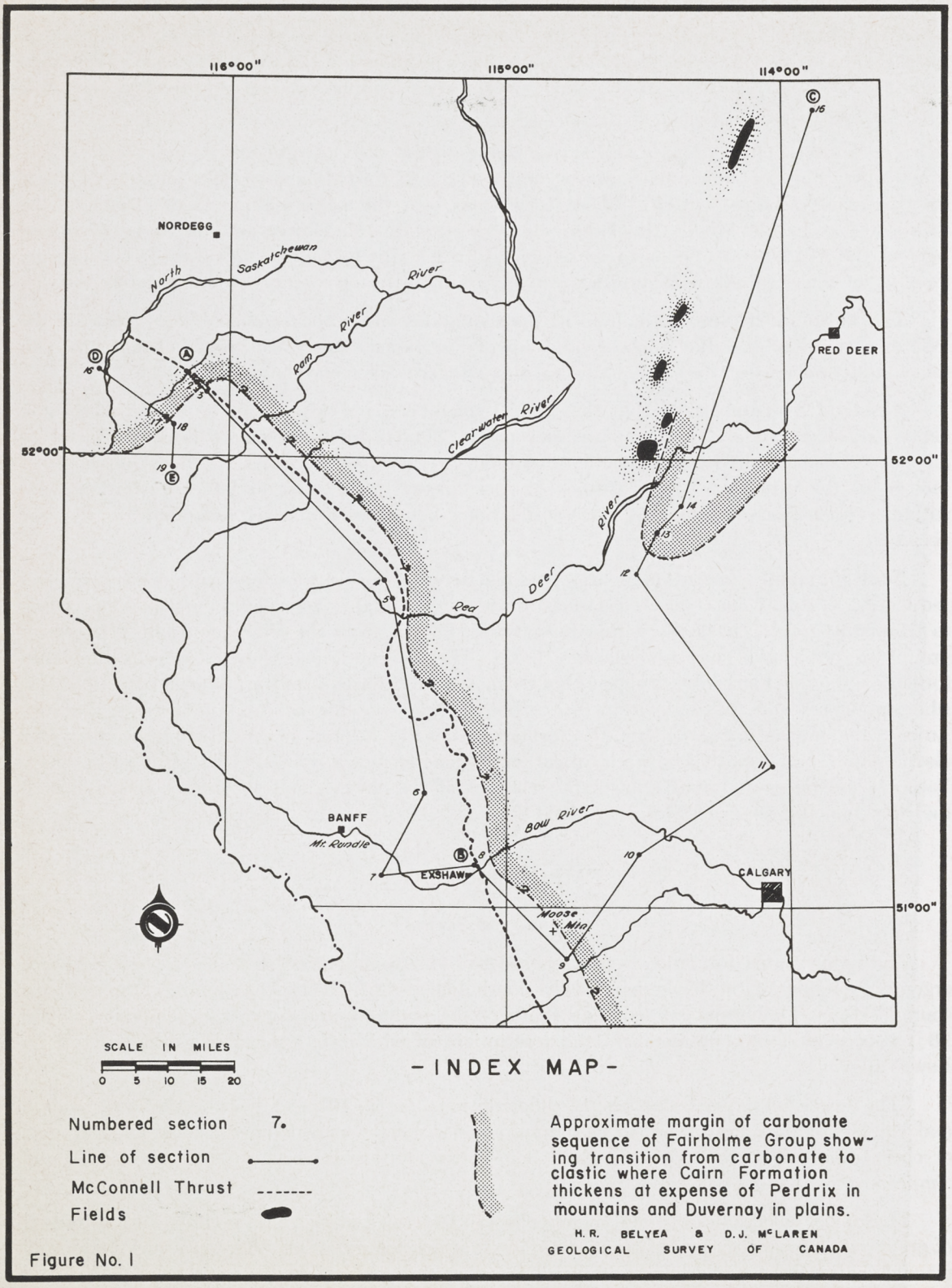

116°00"
115°00"
114°00"
52°00"
51°00"
NORDEGG
North Saskatchewan River
Ram River
Clearwater River
Red Deer River
RED DEER
BANFF
Mt. Rundle
EXSHAW
Bow River
CALGARY
Moose Mtn
A
B
C
D
E
SCALE IN MILES
0 5 10 15 20
- INDEX MAP -
Numbered section 7.
Line of section
McConnell Thrust
Fields
Approximate margin of carbonate sequence of Fairholme Group showing transition from carbonate to clastic where Cairn Formation thickens at expense of Perdrix in mountains and Duvernay in plains.
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Figure No. 1

corals all of which weather a lighter grey than the matrix. Scattered calcite filled vugs occur and most beds emit a fetid odour when broken. These masses constitute the "black reefs" of McLaren (1953). The thinner bedded units contain fewer stromatoporoids but *Amphipora* is very abundant and tends to be restricted to definite bands, interbedded with laminated and apparently detrital dolomites. These are the "stromatoporoid and *Amphipora* beds" and the "bedded dolomites" of McLaren (1953). Rapid alterations of these dominant types of facies occur and the thick-bedded to massive stromatoporoidal developments appear to be broadly lenticular. There is evidence of numerous breaks in the succession — minor erosion surfaces, channelling, and sudden facies changes. The main diagnostic features of the whole formation are its dark colour and more or less well-bedded, strongly biostromal carbonate character." The lithology and attitude are illustrated in Plate 2A and 2B and Plate 3B.

In Bow Valley, the Cairn varies in thickness from 640 feet at the southeast end of Mount Rundle to 457 feet in the Fairholme Mountains above Lac des Arcs, and 550 feet at the unnamed mountain above Loder's lime plant at Kananaskis hereafter referred to as the Loder's lime plant section. The latter is the most easterly of the mountain sections in Bow Valley. The nearest subsurface sections available are those from wells drilled on the eastern slope of Moose Mountain in the foothills belt (see Figure 2). There the Cairn formation seems to be transitional from the massive carbonate sequence to the clastic sequence, and is somewhat similar to the section at Red Deer Gap and to sections described by Belyea (1956b) in areas bordering the southern Alberta shelf. Thus, in the Elbow Falls No. 2A well, 4 miles southeast of Moose Dome, the Cairn consists of a lower member 225 feet thick composed of brown limestone and crystalline dolomites in which organic structures are common. This lower member seems to be the equivalent of the Cooking Lake formation of the Plains. Of this section, the lower one hundred feet of interbedded limestone and dolomite with thin beds of anhydrite is probably the equivalent of the cherty organic dolomite member of the mountain sections. The upper member in the Elbow Falls No. 2A well consist of about 300 feet of dark brown, cryptograined limestones, in part dolomitic, and interbedded dark brown shale. The lower hundred feet of this member is largely shale. Brachiopod fragments are common. In the McColl Frontenac Moose Mountain No. 1 well, the Cairn formation is composed largely of cryptograined limestones and black shales and in character approaches the Duvernay facies. Thus a transition from the massive dark grey organic dolomite of the Loder's lime plant section to black shale and limestone on the eastern slope of Moose Mountain is indicated, and suggests a Duvernay embayment not far east of the mountain front in this area (see Figures 1 and 2).

Farther east, in Shell Jumpingpound Unit 4, the lower part of the Fairholme consists of mottled light and dark brown crystalline dolomites, with some dark brown shale laminae or partings. Comparison of this type of dolomite with similar dolomite cored in other wells strongly suggests that it is largely organic and similar to that of the Cairn formation of the mountains. This dark brown organic dolomite forms the lower part of the Fairholme group in Shell Crossfield No 1 and Shell West Olds No. A-16-15, as well as in deep wells in the Rimbey-Meadowbrook reef chain (Belyea 1956a). In many of these wells the Cooking Lake formation cannot be separated with any degree of certainty. Hence, it is here recommended that the name Cairn formation be used in the Southwestern Plains of Alberta for the dark brown organic dolomites and limestones that rest on the Beaverhill formation where the Cooking Lake cannot be distinguished as a separate formation.

Transition from the Cairn formation of the carbonate sequence in the plains to the Cooking Lake and Duvernay sequence of central Alberta is illustrated in Figure 2, by Shell West Olds No. A-16-15, Shell Westerdale No. 1, and California Standard Ferrybank No. 2-8 wells. This transition is comparable to that in the mountains from the Cairn formation to the Flume

and Perdrix formations between Hummingbird Creek southeast side and Cline and North Saskatchewan forks (see Figure 3), and between the head of Cripple Creek, southeast side and North Ram River (see Figure 2). The Cairn formation rests on strata of various ages. In the Front Ranges the sub-Cairn beds are referred to the Ghost River formation, of undetermined age; farther west they are referred to the Ordovician (Harker, Hutchinson, and McLaren, 1954). Eastward from the Front Ranges, in the foothills and plains, the Cairn formation rests on the Upper Devonian Beaverhill formation (Belyea, 1956b).

The Cairn formation is transitional upwards to the Southesk formation and forms the base on which the latter was built. In general, it is somewhat more extensive than the Southesk and, about the margins of Southesk developments, is overlain by the black shales and dark limestones of the Perdrix (Mountains) and Duvernay (Plains) formations (see Figure 1, 2 and 3).

SOUTHESK FORMATION

The name Southesk formation was proposed by McLaren (1956), for the massive grey dolomites and dark grey coral beds in the upper part of the Fairholme group. The type section is on the northern spur of Mount Dalhousie, immediately south of the junction of the Southesk and Cairn rivers (Plate 1B). Several informal members were recognized, varying from place to place, three of which are present in sections seen in Bow Valley between Loder's lime plant and Mount Rundle.

At the base of the Southesk in Bow Valley is a lower grey dolomite member, a grey weathering, thick bedded to massive, coarse grained, almost structureless dolomite which grades down to the Cairn formation. The porosity characteristically consists of small vugs that commonly show a general alinement parallel to the bedding. In Bow Valley at the southeast end of Mount Rundle it is about 200 feet thick (see Frontispiece). Biohermal masses separated by thick bedded grey dolomites occur in this formation in the Bighorn Range (see Plate 4A).

This member with essentially the same characteristics can be traced eastward through the Moose Mountain wells into the Southern Alberta Plains, where it ranges from 200 to 300 feet in thickness (see Figure 2). To the east, south, and southeast it passes into evaporites and has been referred to as the dolomite-evaporite unit of the Fairholme group by Belyea (1956a). It seems to correspond to the upper part of the Leduc formation. It is in sharp contact at the top with the succeeding coral bed member.

The coral bed member is an extremely variable unit, generally dark grey but with lighter grey dolomite interbedded. It is medium grained, thick bedded to massive, argillaceous, particularly in the lower part. It is probably the equivalent of the lower part of the Delia formation of the Southern Plains, described by Belyea (1956a). In the Moose Mountain wells this member is a dark dolomite with thin shaly partings. At Jumpingpound it is not distinguishable as such, but seems to be replaced by crystalline, vuggy dolomite. Eastward, across southern Alberta the dark argillaceous dolomites of this member appear to interfinger with reefoid dolomites, for example, at Olds, Carbon, Acme and Drumheller.

The overlying, upper grey dolomite member in Bow Valley is massive to thick bedded, medium to coarse crystalline dolomite, variable in thickness from 150 to 245 feet. It is the probable equivalent of the upper part of the Delia formation of the Southern Plains (see Figure 2).

Tongues of both the coral bed member and the upper grey dolomite member extend far beyond the limits of the lower grey dolomite and interfinger with the Mount Hawk in the mountains, and with the upper Ireton in the plains. This is illustrated in Figures 2 and 3 by sections near the margins of the Cairn- Southesk developments in the mountains, and by Shell West Olds No. A-16-15, Shell Westerdale No. 1, and California Standard Ferrybank No.

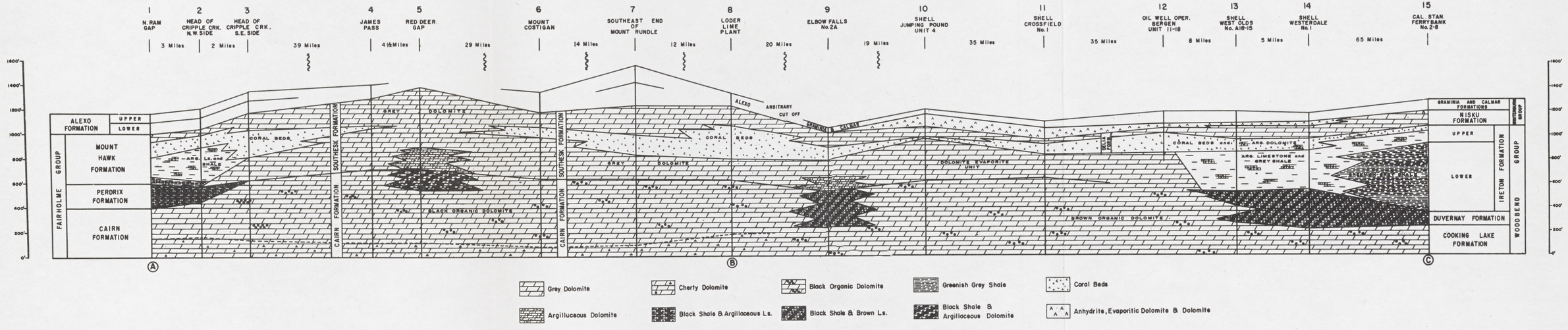


Diagram illustrating thicknesses and facies changes within the Fairholme Group along line A-B-C shown on Figure 1. Correlations of units of Fairholme Group with formations of Woodbend and Winterburn Groups of Central Alberta Plains are suggested. Thicknesses of Alexo Formation are also shown.

Figure No. 2

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2-8 in the Plains. The coral bed section of North Ram Gap, Cripple Creek, Hummingbird Creek, and Loder's lime plant sections is similar to the dark brown, fossiliferous dolomites seen in numerous wells near Wimborne, Pine Lake, Drumheller, Stettler, and the shelf margin reef complex between Drumheller and Vermillion (Belyea, 1956 a, b). This interfingering of coral beds with the upper Ireton shales and shaly limestones was illustrated by Belyea (1956a, Figure 4), although at that time the coral beds were mistakenly believed to consist largely of *Amphipora* and stromatoporoids. The Nisku of the type section in the Leduc oil field appears to be the upper grey dolomite tongue. It exhibits ready changes to evaporites over the shelf margin, c.f. Shell Crossfield No. 1 and Bergen Unit 11-18. A thirty-five foot shaly dolomite immediately below the upper grey dolomite tongue at Cripple Creek is similar to the grey and brown shaly dolomite immediately below the Nisku formation, which, in places, separates the Nisku from the coral beds, where the latter are present.

WOODBEND GROUP

The term Woodbend group is used in the Central Alberta Plains for the clastic sequence equivalent to the Fairholme group of the Southern Plains and mountains. It is discussed only briefly here as it is not present in the outcrop sections of Bow Valley, and has been discussed at length in a number of publications. It is illustrated in Figure 2 by Shell West Olds No. A-16-15 and Shell Westerdale No. 1 wells, drilled near the margin of the Fairholme carbonate sequence and comparable to the section at the head of Cripple Creek, northwest side, and by California Standard Ferrybank No. 2-8, in which the section is somewhat similar to that at the junction of the Cline and North Saskatchewan rivers (see Figure 3). Comparison of other sections farther removed from the margin of the Fairholme carbonate sequence and having thicker greenish-grey, calcareous shales, may be made by reference to reports by McLaren (1956) and Belyea (1956 a, b).

At the base of the Woodbend is the Cooking Lake formation, composed of interbedded stromatoporoid limestones, calcarenites, and calcilutites, but showing considerable lateral variation in lithology. It has been shown (McLaren, 1953, Belyea, 1956a) to contain a fauna similar to that of the Flume formation of the mountains. It thickens similarly to the Flume, at the expense of the Duvernay, toward the carbonate sequence of the Fairholme group to form the Cairn formation, cf. head of Cripple Creek, northwest side with Shell West Olds No. A-16-15 and Shell Westerdale No. 1.

The Cooking Lake is overlain by the interbedded black shales and dark brown limestones of the Duvernay formation, which contains the same fauna as the Perdrix formation. This formation, in turn, is overlain by greenish grey and grey shales of the Ireton formation. These shale-limestone units, both Duvernay and Ireton (plains) and the equivalent Perdrix and lower part of the Mount Hawk (mountains), interfinger with the Cairn and lower part of the Southesk formations near the margins of the Cairn-Southesk carbonate developments. In close proximity to the carbonate banks they include mainly limestones or dolomites with shale interbeds. This interfingering is illustrated by Figure2, in sections at Red Deer Gap, and Elbow Falls No. 2A well, and may also be seen at Wapiabi Creek, northwest side (Belyea, 1954, McLaren, 1956), and in numerous wells in southern Alberta, among which may be noted Socony Morrin No. 1 in Lsd. 15, Sec. 9, Twp. 32, Rge. 19, W4th Mer., Smith C.P.R. No. 1, Lsd. 6, Sec. 4, Twp. 20, Rge. 15, W4th Mer., Homestead Calvan Hamilton Lake in Lsd. 8, Sec. 15, Twp. 35, Rge. 10, W4th Mer., and other wells in eastern and southern Alberta, as well as in the Redwater field. By analogy, a similar relationship is suggested in Figure 2 between Bergen Unit 11-18 and Shell West Olds No. A-16-15.

Near the upper Fairholme carbonate sequence of southern Alberta the upper Ireton is much darker and contains more argillaceous limestone bands and nodules than at a distance from the carbonate sequence. In the immediate vicinity of the carbonate sequence massive fossiliferous limestone beds are common, for example in Shell West Olds No. A-16-15, Shell Wester-

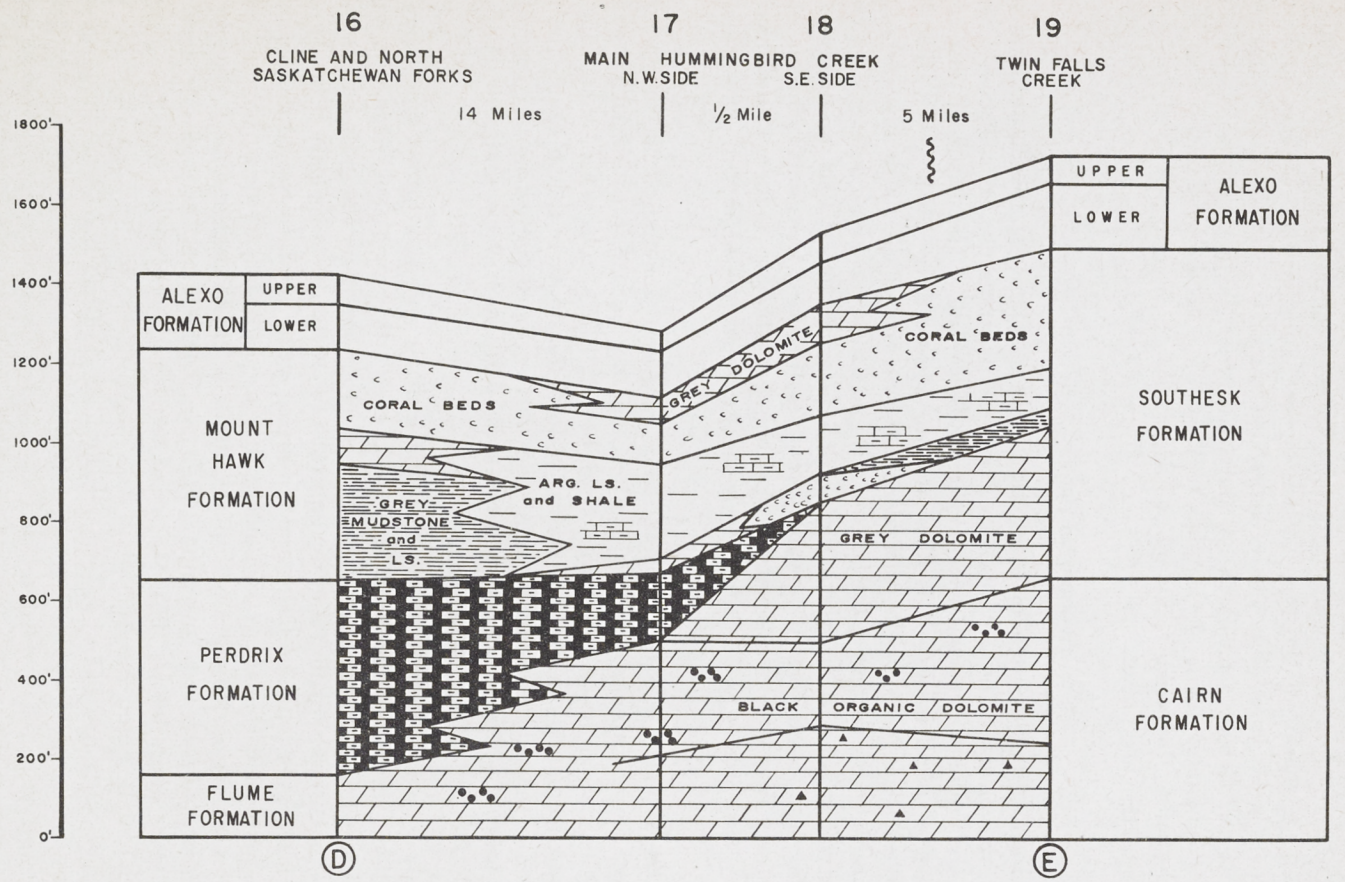


Diagram illustrating thicknesses and facies changes within the Fairholme Group along line D-E shown on Figure 1.

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Figure No. 3

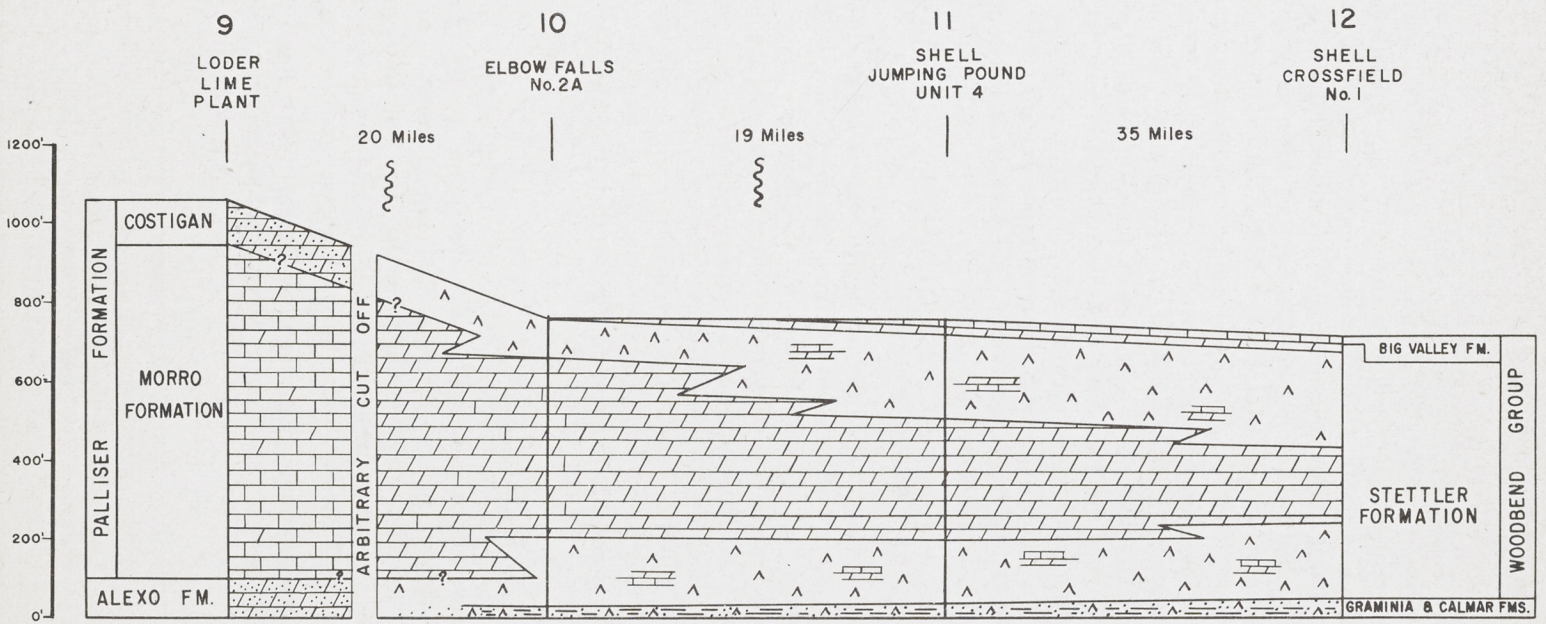


Diagram illustrating facies changes in Wabamun Group and suggesting correlations with Palliser Formation

Figure No. 4

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dale No. 1, and Cripple Creek, northwest side (see Figure 2), as well as in many other wells drilled near the shelf margin between Olds and Drumheller. The upper Ireton and upper Mount Hawk include tongues of coral beds and upper grey dolomite.

ALEXO FORMATION

The Alexo formation has been described by deWit and McLaren (1950), and McLaren (1956). In Bow Valley, in the Fairholme type section (Beach, 1943), it is 108 feet thick; at the head of Cripple Creek it is 172 feet thick. Above Lac des Arcs on the north side of Bow Valley it is 220 feet thick. The section at the southeastern end of Mount Rundle is 333 feet thick, but the upper member is disturbed by faulting. It has been divided into two members by McLaren (1956). The lower member consists of interbedded silty dolomite, dolomitic siltstone, and thick bedded, crystalline dolomite. The upper member consists of argillaceous siltstones and silty dolomites, thin and medium bedded, many of the beds being brecciated and showing contortions. The Alexo rests with a sharp break ,in places with evidence of non-deposition or erosion, on the underlying Fairholme group but is gradational upwards to the Palliser formation. It is considerably thinner over the Fairholme carbonate sequence, including the area covered in this paper, than over the areas where clastic sediments are found, to the north. As it weathers readily and is generally covered with talus, no good exposures are easily accessible in Bow Valley but see Plates 1A and 3A for typical exposures. The section at the southeast end of Mount Rundle is included with the detailed sections.

WINTERBURN GROUP

As orginally defined for the Edmonton area by the Geological Staff of Imperial Oil Limited (1950), the Winterburn was a formation that included the three members, from the bottom up, Nisku, Calmar and Graminia. It was raised to group status and the members given formation rank by Wonfor and Andrichuk (1953). The three formations of the Winterburn are not present, as originally defined, over the carbonate banks of the subsurface Fairholme and the general term Winterburn group is used to include the beds that are believed to be their equivalents. It includes interbedded siltstone, evaporitic dolomite, and anhydrite, and bright green shales in places with coarse sand grains. It may be equivalent to the lower part of the Alexo formation. In all wells examined as far west as Moose Mountain it is thinner than the Alexo formation at Loder's lime plant.

PALLISER FORMATION

The youngest beds of the Devonian are included, in the mountains, in the Palliser formation and, in the plains, in the Wabamun group. Because of lateral variations in lithology and thickness it is not possible to correlate the two units exactly. The Wabamun group may be traced as far west as the Moose Mountain wells; beyond Moose Mountain, in the Front Ranges, the Palliser formation outcrops. Plates 1A and 1B and 4B show typical exposures.

The Palliser formation has been adequately described by Beach (1943), Fox (1951), and deWit and McLaren (1950), who divided it into a lower, Morro, and an upper, Costigan member. Beales (1956) has provided more detailed descriptions of the petrology and conditions of deposition of the formation. In Bow Valley, the Morro member consists of thick bedded to massive, granular limestone characterized by a mottling produced by incomplete dolomitization (Beales, 1953). It forms massive, light weathering, grey cliffs in Bow Valley, where it varies in thickness from 850 feet at Loder's lime plant to 1,050 feet in the section above Lac des Arcs. The Costigan member is a variable succession of thin bedded limestone and dolomite, in places brecciated, and sporadically silty, capped by thin bedded fossiliferous limestone. It varies in thickness from 60 to 414 feet in mountain sections. It can be seen in a road cut on the Calgary-Banff highway just west of the Canada Cement quarry.

As the Palliser in Bow Valley is fairly consistent in lithology and thickness and as it has been described by Beach (1943), and detailed sections have been published by deWit and McLaren (1950), only a summary section is included.

WABAMUN GROUP

The Wabamun group was subdivided by Wonfor and Andrichuk (1953) into the lower, Stettler, and upper, Big Valley formations. These formations can be traced, although with some variation in lithology, from the Stettler area as far west as Moose Mountain. Four informal members were recognized by Belyea (1956b). They are from bottom to top, lower evaporite, lower dolomite, upper evaporite, and upper dolomite. These units can be distinguished in most wells in southern and south-central Alberta, but the evaporites and dolomites interfinger and the units vary in thickness accordingly. More detailed studies as more wells are drilled will show the interrelation of the dolomite and evaporite facies and their correlations. In the McColl Frontenac Moose Mountain No. 1 well a massive limestone overlying the lower evaporite indicates proximity to conditions similar to those of the Front Ranges. However, as both lower and upper evaporite units are present the term Wabamun is extended to include this area. The lower evaporite is probably equivalent to part, if not all, of the upper member of the Alexo formation, this correlation being suggested by the abundance of breccias in the upper part of the Alexo. The upper evaporite may be equivalent to part of the Costigan member. Aside from the above suggestions no detailed correlations can be made between the outcrops of the Palliser formation and the Wabamun group in the Calgary-Olds area.

The Big Valley formation of the Stettler area may be represented by 10 feet of limestone in the Moose Mountain area but the correlation is uncertain.

SUGGESTED COMPARISONS

Some comparison of Fairholme sections (illustrated in Figures 2 and 3) in mountains and plains can be made and some tentative conclusions drawn therefrom. Shell Jumpingpound Unit 4 section is similar to the section at James Pass. The thick upper grey dolomite unit in both, and the massive, dolomitized, richly stromatoporoidal Cairn formation suggest a position for each within a great carbonate build-up.

The section at the southeast end of Mount Rundle seems to represent a position intermediate to Shell Jumpingpound Unit 4 and Shell Crossfield No. 1, in that it has the massive stromatoporoidal Cairn formation, but unlike Jumpingpound Unit 4, has a thick coral bed section, and, unlike Shell Crossfield No. 1, has a massive upper grey dolomite member instead of evaporites.

The section at Loder's lime plant, with a somewhat shaly upper Cairn formation and a thick coral bed section, seems to be relatively near the margin of a carbonate build-up, whereas the sections at Red Deer Gap and Elbow Falls 2A well, with the interfingering shaly limestones and dolomites, may be fairly close to the clastic sequence. Sections on and close to the margins of the carbonate sequences at Hummingbird Creek and at Cripple Creek are analagous to the sections in Bergen Unit 11-18, Shell West Olds No. A-16-15 and Shell Westerdale No. 1.

INDEX OF SECTIONS ILLUSTRATED

1. Northwest side of North Ram River Gap, in Ram Range.
2. Northwest side of Cripple Creek headwaters, in Ram Range, 3 miles southeast of North Ram River Gap.
3. Southeast side of Cripple Creek headwaters.

4. North side of James Pass, 4½ miles north of Red Deer River Gap in Front Range.
5. North side of Red Deer River Gap in Front Range.
6. Southwestern slopes of Mount Costigan, near eastern end of Lake Minnewanka.
7. Southeastern end of Mount Rundle, Bow River Valley.
8. Mountain above Loder's Lime Plant, Kananaskis.
9. Elbow Falls 2A well, eastern slope of Moose Mountain, 4-28-22-6 W5.
10. Shell Jumpingpound Unit 4, 5-7-25-4 W5.
11. Shell Crossfield No. 1 well, 4-22-27-1 W5.
12. Bergen Unit 11-18 well, 11-18-32-4 W5.
13. Shell West Old A-16-15 well, 16-15-33-4 W5.
14. Shell Westerdale No. 1 well, 10-4-34-3 W5.
15. California Standard Ferrybank 2-8 well, 2-8-44-27 W4.
16. Junction of Cline and North Saskatchewan rivers.
17. Northwest side of main branch of Hummingbird Creek.
18. Southeast side of main branch of Hummingbird Creek.
19. Twin Falls Creek.

STRATIGRAPHIC SECTIONS

FAIRHOLME MOUNTAINS ABOVE LAC DES ARCS

The following section was measured on the ridge above the west end of Lac Des Arcs, on the north side of Bow Valley. The ridge forms the southeastern flank of the mountain which lies to the east of Grotto Mountain, and is in the same thrust block.

Palliser Formation

	Thickness in feet
Costigan member	
Grey, variably silty, dolomitic, limestone; thin and medium bedded; medium bedded dolomite at base; some brecciated horizons; upper few feet fossiliferous: *Nudirostra utahensis ventricosa, Cyrtospirifer* cf. *C. kindlei, Strophopleura* cf. *S. notabilis,* nautiloids; thin, cherty and sandy, bone bed at top of member	165
Morro member	
Dark grey to brownish grey, fine and medium grained limestone; thick bedded to massive, with a few thinner bedded rubbly horizons; 20 foot bed of black dolomite at base; lower 250 feet fossiliferous: *Productella* cf. *P. lata, Camarotoechia nordeggi, C.* cf. *C. omaliusi, Cyrtiopsis* cf. *C. normandvillana, C.* cf. *C. standlyensis, Athyris* sp., gastropods and nautiloids	885
Total thickness of Palliser formation	1,050

SOUTHEAST END OF MOUNT RUNDLE, BOW VALLEY

This section is exposed at the southeast end of Mount Rundle above the new road between Canmore and Spray River Valley. It was measured on the north side of the pass, largely in, or on either side of a major gully, normally dry in summer, immediately above the upper of the two lower lakes of the Spray Lakes power project.

The first exposure above the road is of sub-Devonian rocks, which, however, can be better studied farther to the east on the same hillside. The contact with the overlying Fairholme formation is fully exposed.

There are no covered intervals in the succession, but the thicknesses in the Alexo formation are unreliable. There is considerable shattering and contortion in this formation and farther to the east it is steeply folded. The sequence was pieced together over about half a mile of hillside, and is believed to give at least the correct lithological succession and probable approximate thicknesses.

Alexo Formation

Upper member

Unit No.		Thickness in Feet Unit	Total from base
72	Limestone, grey, laminated, fine grained; interbedded with dark grey, coarse grained dolomite; irregular medium bedded	12	1,578
71	Limestone, pale grey, strongly argillaceous, dolomitic, laminated, medium grained; thin bedded	3	1,566
70	Dolomite, grey, calcareous, slightly argillaceous, laminated, medium grained; thin and medium bedded	17	1,563
69	Siltstone, pale orange brown, quartzitic, dolomitic cement, laminated; irregular thin bedded, flaggy; strongly slumped and with well marked current structures	2	1,546
68	Dolomite, brownish grey, silty, laminated, medium grained; irregular medium bedded; soft, pale yellowish grey weathering	10	1,544
67	Dolomite, dark grey, medium to coarse grained; grading downward into paler, finer grained, dolomite; medium bedded	15	1,534
66	Dolomite, dark grey, medium to coarse grained; irregular medium bedding; abundant calcite flecks and veins	15	1,519
65	Dolomite, dark grey, silty, laminated, medium grained; irregular medium bedding; minor current and slump structures; abundant calcite veins	14	1,504
64	Siltstone, pale brownish grey, dolomitic cement; bedding indistinct; towards base becomes increasingly dolomitic	12	1,490
63	Dolomite, brownish grey, silty, laminated, medium grained; irregular medium bedded; minor current marks; some beds strongly silty; fractured and sheared near base	43	1,478
	Thickness of upper member	143	

Lower member

62	Dolomite, dark grey, medium grained; vaguely medium bedded; large numbers of small calcite veins; sheared	57	1,435
61	Dolomite, grey, silty, laminated, medium grained; irregular medium bedding	16	1,378
60	Siltstone, greyish brown, quartzitic, dolomitic cement; irregular medium bedding; weathers pale yellowish grey	3½	1,362
59	Dolomite, grey to dark grey, coarse grained; irregularly medium and thick bedded; small vugs on weathered surface	11	1,358½
58	Shale, greenish grey, calcareous, laminated, medium grained; thin bedded	3½	1,347½
57	Dolomite, dark grey, silty, laminated, fine grained; thin bedded	4½	1,344
56	Limestone, pale brownish grey, fine grained; medium bedded; irregularly altered to grey coarse grained dolomite in patches and lenticular bands	15	1,339½
55	Dolomite, pale grey, coarse grained; medium beds alternating with thin beds of fine grained grey laminated dolomite; a few partings of dark grey calcareous mudstone	17	1,324½
54	Limestone, pale grey, silty, coarse grained; dolomite, pale brownish grey, silty; laminated, medium grained; mudstone, pale greenish grey, calcareous, silty; alternating in thin and medium beds; some brecciated bands	20	1,307½
53	Limestone, pale grey, silty, laminated, fine and medium grained; thin bedded; alternating with grey silty mudstone; silt of angular quartz grains and small amounts of clay minerals; small slump structures and brecciated bands common	11	1,287½
52	Dolomite, grey to dark grey, silty, laminated, coarse grained; thin and medium bedded	9½	1,276½
51	Sandstone, greenish grey, fine grained, quartzitic, dolomitic and pyritic, strongly laminated; thin bedded; very angular quartz sand in dolomitic cement; grades upwards into dolomitic and argillaceous siltstone	4	1,267

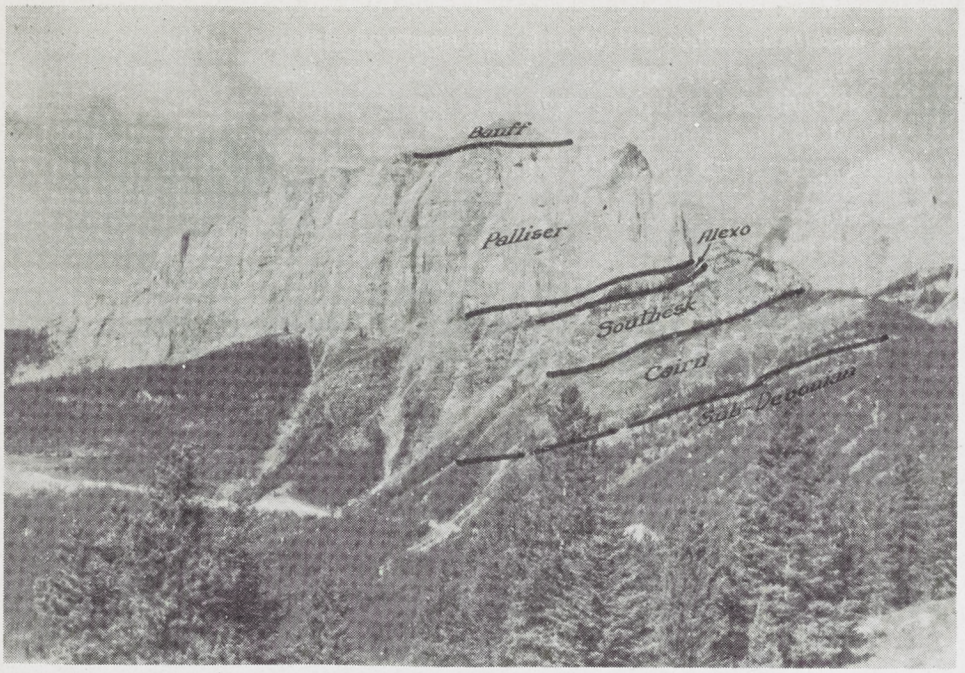


PLATE 1

A Southeast end of Mount Rundle above Canmore, showing typical physiographic expression of Devonian sequence in Bow River Valley. (Geological Survey of Canada photograph).



B Mountains on south side of Southesk River at junction with Cairn River. Type section of Cairn and Southesk formations. (Geological Survey of Canada photograph).



PLATE 2

A Cairn formation, organic dolomite member, southeast end of Mount Rundle above road from Canmore to Spray Lakes. (Geological Survey of Canada photograph).



B Cairn formation, organic dolomite member showing vugs caused largely by leaching of stromatoporoids and other organic remains. (Geological Survey of Canada photograph).

Unit No.		Thickness in Feet Unit	Total from base
50	Sandstone, pale greenish grey, fine grained, quartzitic, dolomitic, argillaceous and pyritic; medium bedded; interbedded with greenish and yellowish grey quartzitic siltstone; sandstone of irregular to angular fine quartz grains, with dolomitic cement and scattered dolomite crystals; siltstone fine angular quarz grains in matrix of dolomite and clay minerals; abundant finely disseminated pyrite throughout whole unit; weathers pale yellowish brown	17	1,263
49	Dolomite, mottled grey and yellowish brown, strongly silty; calcite filled vugs in upper few inches; silt quartzitic, angular	1	1,246
	Thickness of lower member	190	
	Total thickness of Alexo formation	333	

Fairholme Group

Southesk Formation

Upper grey dolomite member

48	Dolomite, pale grey to grey, coarse grained; medium bedded; top bed vuggy and rubbly	18	1,245
47	Dolomite, dark grey, medium grained; irregularly medium bedded; scattered vugs	28	1,227
46	Dolomite, grey, fine to medium grained; thick bedded to massive; irregularly mottled on fresh surface	59	1,199
45	Dolomite, pale grey to grey, fetid, coarse grained; massive, with some vague bedding planes; indistinctly mottled on fresh surface; scattered medium and large vugs	75	1,140
44	Dolomite, grey to pale grey, medium to coarse grained; vaguely thick bedded to massive; vugs developed in bands, and irregular masses of calcite; a few bands with traces of *Amphipora*	36	1,065
43	Dolomite, grey, coarse grained; thick bedded; flecked with white calcite masses and filaments; a few vaguely defined *Amphipora* near base	28	1,029
	Thickness of upper grey dolomite member	244	

Coral bed member

42	Dolomite, dark grey, medium grained; medium to thick bedded; some beds of paler grey dolomite (up to 2 feet in thickness); abundant *Amphipora* and tabulate corals	24	1,001
41	Dolomite, brownish grey, fine to medium grained; massive; scattered vugs and cavities on weathered surface	13	977
40	Dolomite, black, brownish grey to grey, medium to coarse grained; medium bedded; a variable series of interbedded black and dark grey with paler grey dolomites; largely without organic traces; a few with *Amphipora*	40	964
39	Dolomite, interbedded black and dark grey to grey, slightly argillaceous, fetid, coarse grained; medium to thick bedded; a rhythmic alternation of black faintly laminated coarse grained dolomite with grey, finer grained dolomite (2 to 5 foot alternations)	51	924
38	Dolomite, grey, medium grained; massive; vuggy towards base	21	873
37	Dolomite, black, fetid, medium grained; thick bedded; two beds of pale grey dolomite; *Amphipora* and coral traces	11	852
	Thickness of coral bed member	160	

Lower grey dolomite member

36	Dolomite, pale grey to grey, porous, coarse grained; massive to vaguely thick bedded; small vugs partly calcite filled; large cavities on weathered surface; prominent bedding plane 50 feet from base	132	841
35	Dolomite, pale grey, slightly argillaceous, strongly fetid, porous, coarse grained; massive; mottled and indistinct granular markings; large vague circular markings on weathered surfaces	39	709

Unit No.		Thickness in Feet Unit	Total from base
34	Dolomite, black, slightly argillaceous, medium grained; single bed; abundant tabulate corals and gastropods; irregular top and bottom, lenses out along hillside	3	670
33	Dolomite, similar to unit 35, single bed	4½	667
32	Dolomite, similar to unit 34, lenticular in levelopment along hillside	5	662½
31	Dolomite, pale grey, slightly argillaceous, fetid, porous, medium to coarse grained; massive; coarse granular mottling in section, with patches and filaments of clear dolomite; residue of pale clay minerals; *Amphipora* abundant in lowest 2 feet	18	657½
	Thickness of lower grey dolomite member	201½	
	Total thickness of Southesk formation	605	

Cairn Formation

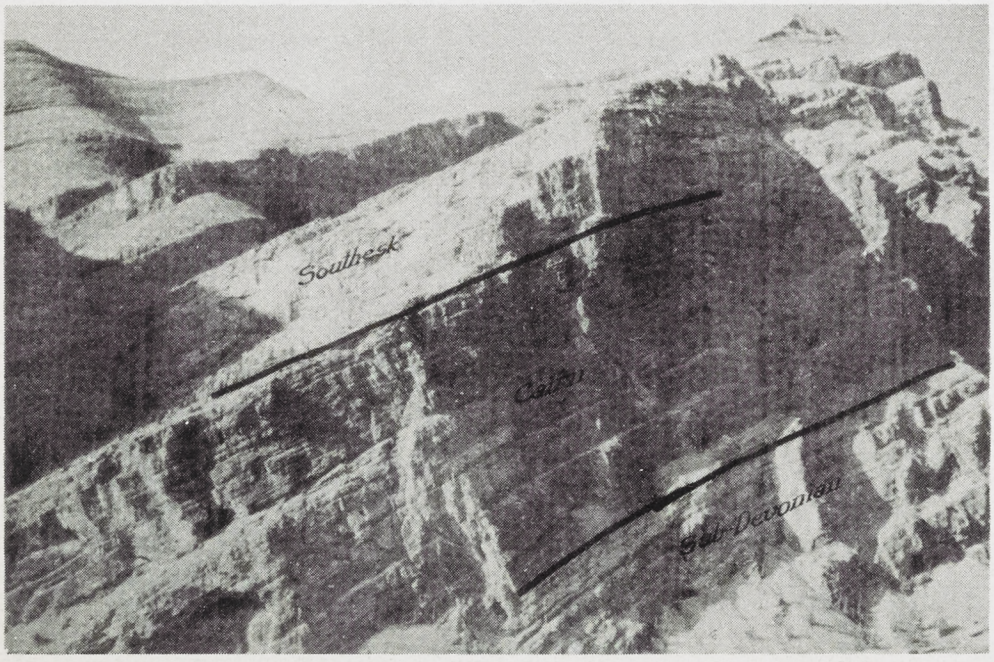
Black organic dolomite member

30	Dolomite, black, slightly argillaceous, fetid; massive; composed largely of *Amphipora*, stromatoporoids, and tabulate corals; abundant vugs, partly calcite filled; calcite veins common	10	639½
29	Dolomite, dark grey, faintly laminated, medium grained; medium bedded with some beds of pale grey dolomite	22	629½
28	Dolomite, dark grey to black, medium grained; massive; regularly arranged small vugs, partly calcite filled which simulate true bedding; *Amphipora* and corals near top and bottom of unit, but main body without organic traces except for scattered brachiopod and gastropod fragments	46	607½
27	Dolomite, grey to dark grey in alternating beds, fetid, laminated, medium grained; medium to thick bedded; *Amphipora* abundant in some beds	29	561½
26	Dolomite, pale grey, coarse grained, porous; single bed; abundant small vugs; contact with unit below very irregular	6½	532½
25	Dolomite, black, fetid, fine grained; much of rock composed of grey stromatoporoid and coral remains; massive; calcite filled or lined vugs abundant, linearly arranged	13	526
24	Dolomite, grey to black, fetid, laminated, fine to medium grained; medium bedded; abundant *Amphipora* in bands; base very irregular	26	513
23	Dolomite, black, slightly argillaceous, fetid, medium grained; more than 50% of rock composed of grey stromatoporoids with subordinate *Amphipora* and corals; massive; large calcite lined vugs (½ to 18 inches diameter) after or contained within stromatoporoids, linearly arranged, forming structure lines; and small (c.0.1 mm. diameter) spheres; microscopic bedding apparent; an increase in *Amphipora* and vague bedding towards base	137	487
22	Dolomite, grey, medium grained, laminated; medium beds alternating with black dolomites with abundant *Amphipora* and stromatoporoids; junction with underlying unit irregular and transgressive to bedding	22	350
21	Dolomite, pale grey, coarse grained; massive; large cavities on weathered surfaces; thickens rapidly northwards along mountain-side, broadly lenticular	27	328
20	Dolomite, dark grey to black, slightly argillaceous, porous, fetid, sporadically laminated, medium grained; thick bedded; black flocculent residue; small cavities (up to 2 mm. diameter) arranged along bedding; scattered vugs after stromatoporoids	18	301
19	Dolomite, black, argillaceous, fetid, medium grained; massive; scattered calcite filled vugs; abundant grey Amphipora and coral traces	15	283
18	Dolomite, dark grey to black, argillaceous, laminated, medium grained; thin and medium bedded; a few thin beds rich in *Amphipora*	14	268
17	Dolomite, black, argillaceous, fetid, medium grained; massive; scattered light grey coral remains	15	254
16	Dolomite, black with organic traces grey, argillaceous, medium grained; sporadically laminated; medium bedded; abundant traces of *Amphipora*, massive stromatoporoids, tabulate corals, brachiopods, and gastropods, all occurring in bands	42	239
15	Dolomite, black, argillaceous, fetid, laminated at base, fine to medium grained; massive	17	197



PLATE 3

A Alexo formation showing sharp contact between upper and lower members. This section is on Job Creek, west side, eastern fault block. (Geological Survey of Canada photograph).

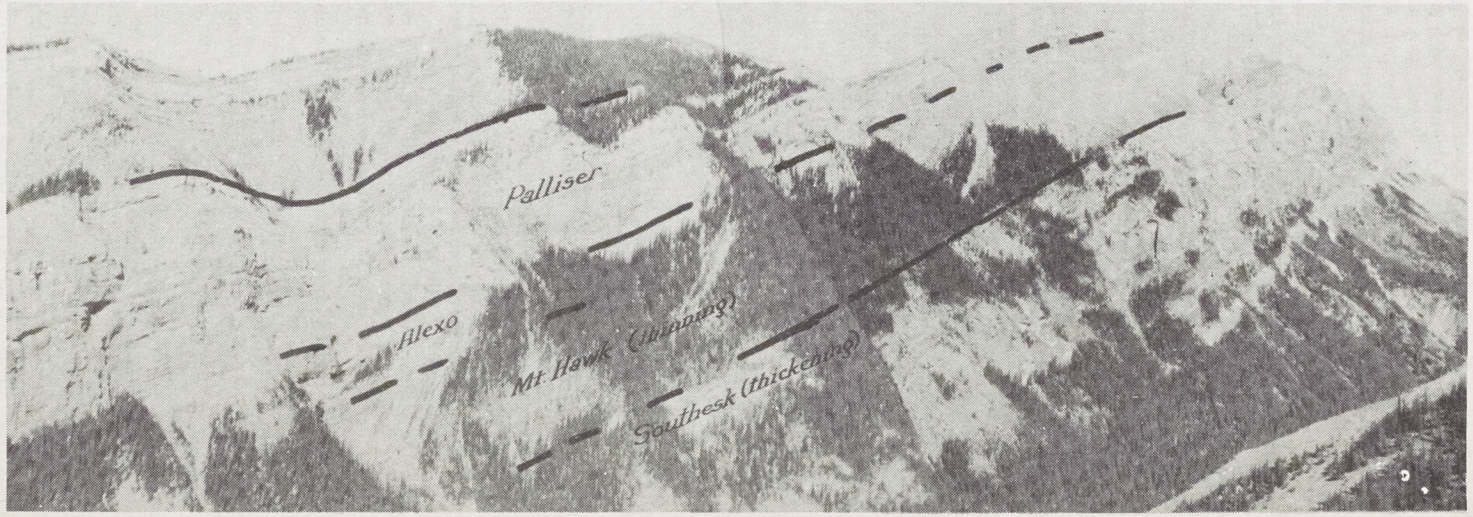


B Massive development of Southesk and Cairn formations, James Pass, looking north. (Geological Survey of Canada photograph).



Plate 4:

A Face of Bighorn Range on northwest side of Wapiabi Creek, showing discontinuous biohermal masses separated by thick-bedded grey dolomite of the Southesk formation. (Geological Survey of Canada photograph).



B Bighorn Range looking northwest from above Wapiabi Creek shows Southesk formation thickening and Mount Hawk formation thinning to northwest. (Geological Survey of Canada photograph).

Unit No.			
14	Limestone, grey with black mottling, fine grained, laminated; grading downwards into black, fine grained dolomite with some interbedding; thin and medium bedding; weathers pale yellowish grey at top and dark grey below	13	180
13	Dolomite, dark grey to black, argillaceous, slightly silty, fetid, fine and medium grained; thick bedded to massive; calcite filled vugs after stromatoporoids common; thin slip-plane (?) breccia at base; very abundant *Amphipora, Stachyodes,* massive stromatoporoids, corals and *Atrypa* which weather paler grey; all recrystallized	56	167
12	Dolomite, dark grey to grey, argillaceous, fine grained at base becoming coarser upwards; medium to thickbedded; abundant small calcite filled vugs and filaments; traces of stromatoporoids	15½	111
	Thickness of black organic dolomite member	544	

Basal dolomite member

11	Dolomite, dark grey, medium grained; two thinner bands of pale grey dolomite; rare chert lenses	19	95½
10	Dolomite, brownish grey, silty, fine grained, laminated; current bedded; closely resembles sub-Devonian facies	1½	76½
9	Dolomite, grey, fine to medium grained, laminated; medium bedded in 4 to 8 ft. units alternating with darker, fetid, dolomite with traces of stromatoporoids; a few lenticular bands of black chert	16	75
8	Dolomite, dark grey, medium grained; medium bedded; abundant calcite filled vugs and filaments; traces of *Amphipora* and stromatoporoids	3	59
7	Dolomite, grey, slightly silty, medium grained; medium bedded; slightly laminated; scattered small calcite filaments	5½	56
6	Dolomite, black, argillaceous, medium grained; medium bedded, traces of *Atrypa*	7	50½
5	Dolomite, black, fetid, calcareous, medium grained; interbedded in six regular alternations with grey, laminated, dolomitic limestone; medium bedded; sporadic development of thin pebble beds; weathering emphasizes the colour differences	11½	43½
4	Dolomite, dark grey to black, argillaceous, fine and medium grained; medium bedded; scattered small round calcite bodies; rock slightly mottled and vaguely granular	12	32
3	Dolomite, pale grey, calcareous, alternating with grey laminated and black argillaceous dolomites, all medium grained; medium bedded upper 6 inches brecciated with a mixture of lithologies in fragments from beds above and below; possible slip plane?	7	20
2	Dolomite, black, medium grained; in medium beds grading, without a break, upwards into pale grey quartzite siltstone with dolomite cement; laminated and current marked; colour change prominent when weathered	4	13
1	Dolomite, variably grey, dark grey and mottled, slightly argillaceous and silty, fine grained; medium bedded, with darker mottled beds alternating with lighter laminated and silty dolomite (4 to 6 inch beds); mottled beds faintly granular and fragmental, with small calcite filled cavities	9	9
	Thickness of basal dolomite member	95½	
	Total thickness of Cairn formation	640	
	Total thickness of Fairholme group	1,245	

UNNAMED MOUNTAIN ABOVE LODER'S LIME PLANT, KANANASKIS

This section was measured on the southeast face of the mountain above Bow Valley. A detailed description of this section was published by Beach (1943). A summary section is included here indicating formations and members proposed by McLaren (1956). Thickness of the Cairn formation is unreliable in that minor thrust faulting seems to have duplicated some of the section. J. M. Andrichuk and R. H. Erickson (personal communication) on another part of the mountain face measured only 386 feet of Cairn formation.

Fairholme Group

Southesk Formation

Upper grey dolomite member	Thickness in Feet	
	Unit	Total from base
Dolomite, grey to brownish grey, medium to coarse grained, medium to thick bedded; weathers light grey; in general with small vugs abundant; scattered *Amphipora* beds	170	1,188
Thickness of upper grey dolomite member	170	
Coral bed member		
Dolomite, brown, fine grained, grey weathering, argillaceous; wavy irregular partings between beds; a few *Amphipora* and corals; section partly covered	36	1,018
Dolomite, dark brownish grey, fine grained, thin bedded to massive; abundant *Amphipora* in layers; corals common; interbeds of dark brown laminated dolomite	41	982
Dolomite, dark grey, fine to medium grained with lateral variation of grain size and texture; lenses of breccia; vuggy porosity in patches; dark grey to ochre weathering; sharp contact at top with iron oxide stains and calcite along contact; 4′ of light grey, thick bedded dolomite at top	36	941
Dolomite, dark grey to black, fine grained, argillaceous, tight; 2 foot light grey interbed; breccia or boulder bed at base	28	905
Thickness of coral bed member	141	
Lower grey dolomite member		
Dolomite, grey, fine to coarse grained, thick bedded to massive, light grey weathering; some beds laminated; some beds with vugs alined parallel to bedding	239	877
Dolomite, dark grey, fine grained; rubbly weathering with wavy bedding; shale laminae; corals; *Amphipora* beds	20	638
Dolomite, grey, fine to medium grained, massive; small vugs parallel to bedding; bottom 25 feet has brecciated appearance; fine clear calcite and dolomite	64	618
Thickness lower grey dolomite	323	
Total thickness of Southesk formation	634	

Cairn Formation

Black organic dolomite member		
Dolomite, dark grey to black, fine to medium grained, massive; abundant stromatoporoids, corals, *Amphipora;* stromatoporoids largely weathered out; upper 20 feet exposed, less massive than below, 20 feet covered at top	178	554
Dolomite, dark grey, fine grained, cyclical alternation of massive stromatoporoidal dolomite beds 20 to 40 feet thick and grey, fine grained, laminated dolomite; *Amphipora* beds common; beds with algal structures change laterally to stromatoporoid beds	106	376
Dolomite, brownish grey to black, thin bedded, argillaceous, laminated; partly covered	16	270
Dolomite, black, massive, indistinct bedding; stromatoporoids, corals; basal part has boulder-like appearance; upper 2 feet light grey weathering grey dolomite	50	254
Thickness of black organic dolomite member	350	
Cherty dolomite member		
Dolomite, dark grey to black, fine grained, thin to thick bedded; stromatoporoid beds 2′ to 3′ thick; *Amphipora* beds; alternating laminated beds; chert as nodules and replacing stromatoporoids in upper part	197	204
Limestone, dark grey to black, thin bedded to platy; *Atrypa multicostellata* Kottlowski, *Eleutherokomma* cf. *E. jasperensis* (Warren), *Allanaria minutilla* Crickmay?	7	7

	Thickness in Feet	
	Unit	Total from base
Thickness of cherty dolomite member	204	
Total thickness of Cairn formation	554	
Total thickness of Fairholme group	1,188	

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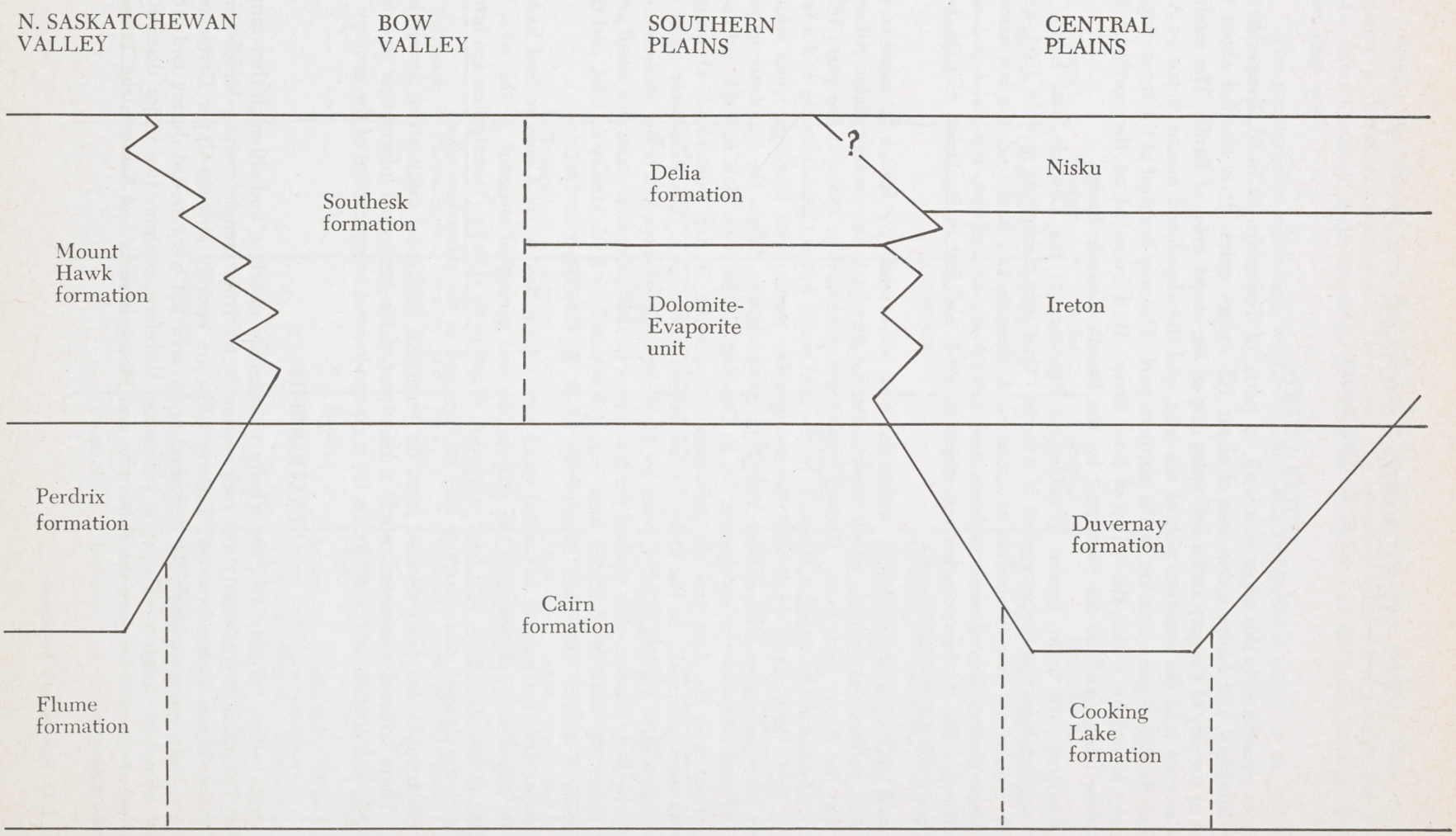
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FORMATIONS	1	2	3	4	5	6	7	8	9	10	11	12
	PALLISER		ALEXO	MT. HAWK	PERDRIX	FLUME		IRETON	DUVERNAY	COOKING LAKE		BEAVERHILL
MEMBERS	Costigan	Morro				Upper	Lower			Upper	Lower	
FAUNA												
Leioproductus plicatus (Kindle)	X											
Nudirostra utahensis ventricosa (Haynes)	X											
Paurorhyncha cascadensis (Warren)	X											
Cyrtospirifer kindlei Stainbrook	X											
Strophopleura notabilis Kindle	X											
Athyris sp.	X	X										
Camarotoechia nordeggi Kindle	X	X										
Schuchertella sp.	X	X										
Leioproductus coloradensis (Kindle)		X										
Camarotoechia banffensis Warren		X										
C. cf. C. sobrina Stainbrook		X										
Nudirostra gibbosa seversoni McLaren		X										
N. cf. N. jeffersonensis (Haynes)		X										
Cyrtiopsis normandvillana Crickmay		X										
Tenticospirifer cf. T. conoideus (Roemer)		X										
Theodossia ? sp.		X										
Cranaena sp.		X										
Styliolina sp.			X									
Leioproductus sp.			X									
Productella spp.			X									
Nudirostra gibbosa walcotti (Haynes)			X									
Pugnoides sp.			X									
Atrypa sp.			X									
Cyrtospirifer portae Merriam			X									
Warrenella n. sp.			X									
Athyris angelicoides Merriam			X									
Leptodesma sp.			X									
Echinocaris sp.			X									
Hexagonaria bassleri (Webster & Fenton)								X				
H. minuta (Stumm)				X								
Pachyphyllum ex. gr. P. nevadensis (Stumm)				X								
Synaptophyllum cf. S. grundinaceum (Billings)				X				X				
S. cf. S. stramineum (Billings)				X				X				
Schizophoria iowensis (Hall)				X				X				
S. cf. S. mcfarlanei (Meek)				X								
Gypidula cf. G. cornuta Fenton & Fenton				X								
Douvillina arcuata (Hall)								X				
Douvillinaria sp.				X								
Nervostrophia sp.				X				X				
Schuchertella prava (Hall)								X				
Devonoproductus walcotti (Fenton & Fenton)				X								
Hypothyridina cf. H. emmonsi (Hall & Whitfield)				X								
Nudirostra albertensis (Warren)				X				X				
N. cf. variabilis (Whiteaves)								X				
Pugnoides calvini Fenton & Fenton				X								
Atrypa devoniana Webster				X				X				
A. montanensis Kindle				X								
Grunewaldtia cf. G. americana Stainbrook				X								
Cyrtospirifer gradatus (Fenton)								X				
Cyrtospirifer cf. C. whitneyi (Hall)				X				X				
Indospirifer orestes (Hall & Whitfield)				X				X				
Tenticospirifer cf. T. cyrtiniformis (Hall & Whitfield)				X				X				
Theodossia sp.								X				
Cyrtina iowaensis Fenton & Fenton								X				
Conocardium sp				X								
Manticoceras sp.				X		X						
Tentaculites sp.				X	X	X		X	X	X		
Thomasaria rockymontana (Warren)				X	X							
Warrenella nevadensis (Walcott)				X	X							
Lingula sp.					X							
Calvinaria? inelegans McLaren					X				X			
Nudirostra insculpta McLaren					X				X			
Atrypa sp.					X				X			
Buchiola dilata Kindle					X							
Echinocaris sp.					X							
Entomis sp.					X							
Eleutherokomma cf. E. jasperensis (Warren)					X	X			X	X		
Buchiola sp.					X	X						
Stropheodonta sp.						X				X		
Productella sp.						X						
Nudirostra athabascensis (Kindle)						X				X		
Allanaria minutilla Crickmay						X				X		
Ambothyris sp						X						
Athyris parvula Whiteaves						X						
Bactrites cf. B. gracilor Clarke						X						
B. cf. B. warthini Miller						X						
Atrypa multicostellata Kottlowski						X	X			X	X	
Eleutherokomma cf. E. killeri Crickmay						X	X			X	X	X
E. cf. leducensis Crickmay						X				X	X	
Spongophyllum sp.											X	
Schizophoria sp.							X				X	
Schuchertella sp.							X					
Productella sp.							X				X	
Pugnoides kakwaensis McLaren							X					
Spinatrypa albertensis (Warren)							X				X	
Allanaria allani (Warren)											X	
Eleutherokomma hamiltoni Crickmay											X	
cf. Strophalosia sp.												X
productellids												X
small stropheodontids												X
Atrypa spp.												X

TABLE II

Rhynchonellid Zones	*Mountains*		*Plains*
Nudirostra utahensis ventricosum	Costigan	Palliser	Wabamun
Nudirostra gibbosa seversoni	Morro		
Nudirostra gibbosa walcotti	Alexo		- - ? - - - - - - - ? - - - - Winterburn
Nudirostra albertensis	Mount Hawk		- - - ? - - - - - - - ? - - - - Ireton
Nudirostra insculpta	Perdrix		Duvernay
Nudirostra athabascensis	Upper	Flume	Cooking Lake
Pugnoides kakwaensis	Lower		
			- - - - - - - - - - - - - - - - Beaverhill



Formations of Upper Devonian Fairholme Group in carbonate and clastic sequences in Mountains and Plains of Alberta

THE CANMORE COAL BASIN

M. B. B. CROCKFORD[1]

INTRODUCTION

The area considered in this paper covers all, or parts, of Townships 24 to 26, Ranges 10 to 12, W.5th Meridian, and comprises an area of about 125 square miles. It is situated about 80 miles west of the city of Calgary and a few miles east of the resort town of Banff. The mining town of Canmore is in the southern part of the area, and the abandoned mining towns of Anthracite and Bankhead were situated in the northern part. The area lies west of the front ranges of the Rocky Mountains within the valley of Bow River. It is bounded on the northeast by the Fairholme Range, and on the southwest by the Rundle-Cascade Range.

The Canmore coal basin, known in geological literature as the Cascade coal basin, is the oldest mining district in the mountains of Alberta. Coal was discovered in it in 1883, and mines were opened not long afterwards at Canmore, Anthracite, and Bankhead, the last named in 1888. These centres thrived when coal was used extensively for railway, industrial and domestic purposes. The Anthracite mine was closed in 1904, and that of Bankhead in 1923, but the Canmore mine still produces coal.

The first geological investigations within the area were made by Hector, a member of Captain John Palliser's expedition, which made extensive surveys in the western plains, Alberta foothills, and the Rocky Mountains. Hector's report was published in 1863. In the years 1881 to 1884, G. M. Dawson gave some attention to the coal seams in the Cascade basin, and a few years later, R. G. McConnell subdivided the stratigraphic section into lithologic units which to this day have undergone little revision except in nomenclature. When the economic importance of the coal deposits was recognized, D. B. Dowling, in the years 1902 to 1923, did considerable research in the area and his publications respecting it are numerous. Dowling's observations refer principally to the Mesozoic formations in the area. The Palaeozoic rocks of the general area were studied in later years by H. W. Schimer, who worked in the Minnewanka Valley, and by P. S. Warren, who studied the Banff area in 1926. The coal seams in a small area centering about the town of Canmore were mapped in detail by B. R. McKay in 1934, and the area adjoining it on the south was mapped by M. B. B. Crockford in 1947.

This paper does not purport to present much new information on the Canmore coal basin, but is to be considered a summary of the stratigraphy and geological structure of the area, as reported by various geologists who have worked in it and in its vicinity. Descriptions are brief, for details of stratigraphy and structure may be obtained in the references cited.

The bibliography has been selected from the numerous geological publications respecting this area. These selected references supply a large part of the geological information reported in this paper, and contain sufficient details for a comprehensive interpretation of the geology of the area.

STRATIGRAPHY

The strata within the map area are wholly sedimentary in origin, and although they range in age from Devonian to Quaternary, the rock section is far from complete since Middle and Upper Triassic, Upper Cretaceous, and Tertiary rocks are entirely absent. Upper Cretaceous and Tertiary rocks were undoubtedly deposited in the area but were eroded during and after the Rocky Mountain orogeny. The rock succession, therefore, contains two major disconformities. These are present between the Palaeozoic and Mesozoic rocks and between the Triassic and Jurassic systems.

[1] Geologist, J. C. Sproule and Associates.

Within the subject area the Palaeozoic rocks, being more resistant than the Mesozoic, occupy a dominant position and they form the mountain masses that contain the Bow Valley. The softer Mesozoic rocks constitute the floor of the valley and the lower western slopes within the map area.

The stratigraphic succession within the area and its vicinity is shown in the following table of formations.

Group	*System*	*Series*	*Formation*	*Character*	*Thickness (feet)*
Cenozoic	Quaternary	Recent and Pleistocene		Soil, gravel, silt, talus, boulder clay.	
			Unconformity		
Mesozoic	Cretaceous	Lower Cretaceous	Blairmore	Green, grey, black and maroon shales, interbedded with grey and greenish-grey sandstones; limestone nodules; conglomerates, and massive conglomerate at base.	Only lower part present 1,000+
			Contact apparently conformable		
			Kootenay	Dark grey and black shales, interbedded with fine grained, silty sandstones, dark grey, coarse grained sandstones; conglomerate beds near top; coal seams; thick sandstone member at base.	3,400
	Jurassic	Upper Middle Lower	Fernie	Fine grained, grey sandstone at top; greenish, grey, dark grey and black shale; ironstone nodules and stringers.	1,095
			Unconformity		
	Triassic	Lower	Spray River	Dark grey, sandy shale and shaly, fine grained sandstone, dolomitic shales and argillaceous dolomite; limestone.	600
			Unconformity		
Palaeozoic	Carboniferous	Permian and Pennsylvanian	Rocky Mountain	Quartzite, quartzitic sandstone, and dolomite.	625
		Mississippian	Rundle	Limestone, argillaceous limestone, dolomite, black, red green shale; chert.	1,800 to 2,400
			Banff	Limestone, argillaceous limestone, and calcareous shale.	1,400 to 1,500
			Exshaw	Black, argillaceous limestone and black shale.	30 to 75
			Disconformity (?)		
	Devonian	Upper Devonian	Palliser	Massive limestone and dolomite limestone.	1,000
			Fairholme	Black, fine grained dolomite and minor silty shale.	1,300 to 1,900
?	?		Ghost River	Dolomite and dolomitic shale.	150 to 300

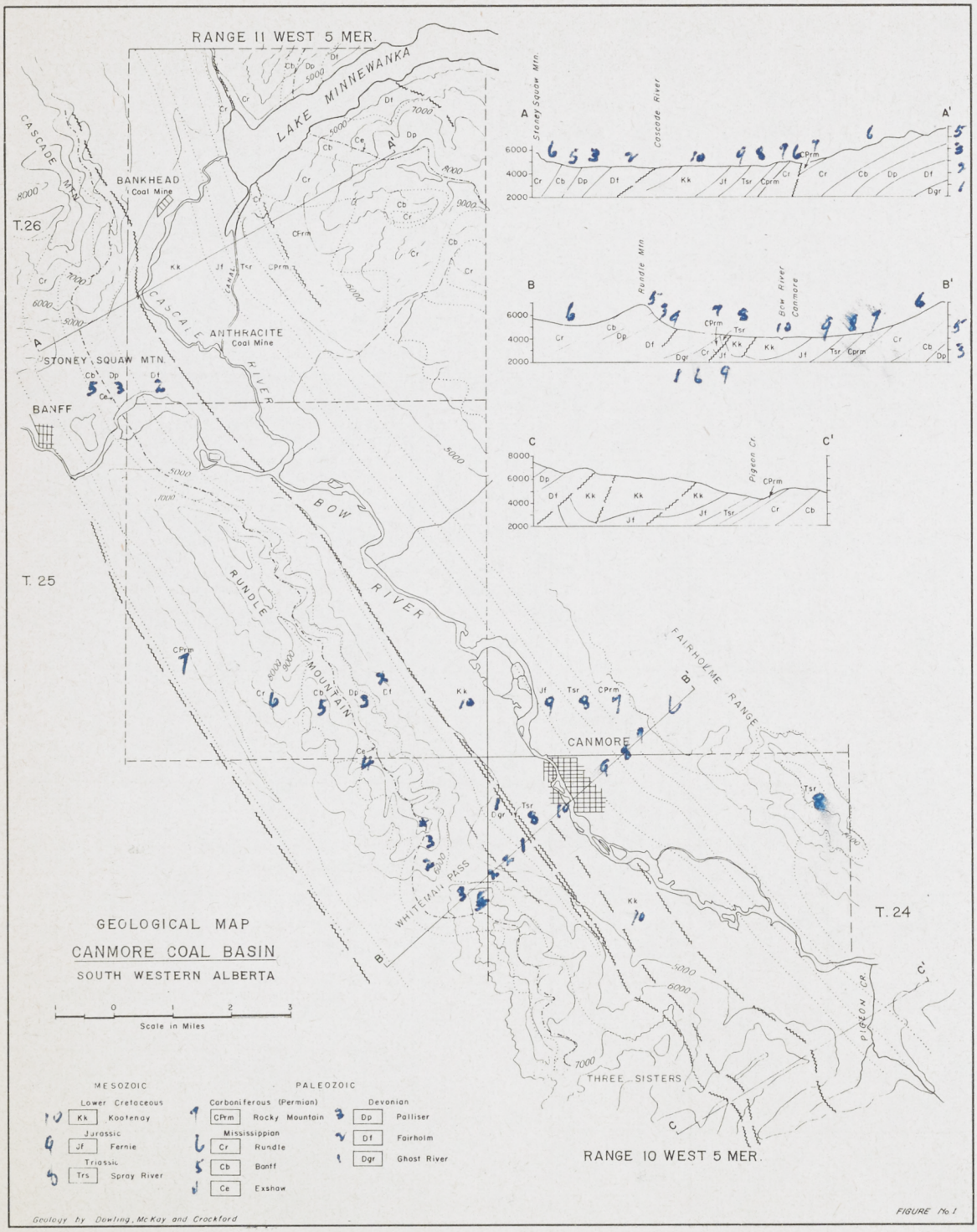

RANGE 11 WEST 5 MER.
LAKE MINNEWANKA
CASCADE MTN.
BANKHEAD
Coal Mine
T.26
CASCADE ANTHRACITE
Coal Mine
STONEY SQUAW MTN.
BANFF
BOW RIVER
RUNDLE MOUNTAIN
T. 25
FAIRHOLME RANGE
CANMORE
WHITEMAN PASS
T. 24
THREE SISTERS
PIGEON CR.
RANGE 10 WEST 5 MER.
A
A'
B
B'
C
C'
Stoney Squaw Mtn.
Cascade River
Rundle Mtn
Bow River
Canmore
Pigeon Cr.
GEOLOGICAL MAP
CANMORE COAL BASIN
SOUTH WESTERN ALBERTA
Scale in Miles
MESOZOIC
Lower Cretaceous
Kk Kootenay
Jurassic
Jf Fernie
Triassic
Trs Spray River
PALEOZOIC
Carboniferous (Permian)
CPrm Rocky Mountain
Mississippian
Cr Rundle
Cb Banff
Ce Exshaw
Devonian
Dp Palliser
Df Fairholm
Dgr Ghost River
Geology by Dowling, McKay and Crockford

FIGURE No. 1

Ghost River Formation

This formation consists essentially of fine grained thinly bedded dolomite, which weathers to a characteristic light buff color. Associated with the dolomite are green and red dolomitic shales. The formation outcrops on the slopes west of the town of Canmore and good exposures can be seen along the road over White Man Gap. The thickness of the formation as given by Clark (1949, p. 623) is from 150 - 170 feet, in the Kananaskis River gap. Warren estimates a thickness of 300 feet for the Banff area.

The age of the Ghost River formation is generally considered to be Devonian, due to its stratigraphic position, for to date no useful fossils have been found in it. However, there are some workers who would assign to it a Cambrian age.

Fairholme Formation

This formation consists essentially of dark grey and black, fine grained dolomite. It is less resistant than the overlying Palliser and, therefore, on the west side of the Bow Valley within the map area forms the mountain slopes below the precipitous Palliser cliffs. Good exposures of Fairholme, containing stromatoporoidal reefs, can be seen along the road to White Man Gap mentioned above. The formation, as measured by Warren (1927, p. 16) on Sulphur Mountain, is 1,900 feet thick. In the front ranges it is estimated to be 1,300 feet thick (Clarke, 1949, p. 625).

Palliser Formation

The Palliser formation is very prominent throughout the mountains, as it forms numerous vertical cliffs many hundreds of feet in height. It consists essentially of massive limestone and dolomite beds. Some thin, very fossiliferous, limestone beds compose the upper 50 to 100 feet. The formation is 1,000 feet thick in the Banff area according to Warren (1927, p. 19).

The quarry of the Exshaw cement plant along the highway immediately west of that town is in the uppermost part of this formation.

Exshaw Formation

This formation overlies the Palliser with a slight disconformity, as seen in an exposure on the west slope of Wedge Mountain in the Kananaskis area, immediately southwest of the area under discussion. There the surface of the Palliser is pitted and abundant pyrite is present at the contact. Moreover, there is an abrupt change from Palliser limestone to Exshaw shale. The age of the Exshaw has not been definitely determined, but the present consensus of opinion places it in the Mississippian. The formation has a thickness of about 75 feet. It consists of black limestone overlying black, fissile shale.

Banff Formation

This formation consists of an alternating sequence of limestone, argillaceous limestone, and calcareous shale. It forms a relatively gentle slope above the precipitous Palliser limestone on the west wall of the Bow Valley within the map area. The thickness of the formation is from 1,400 to 1,500 feet. Warren gives a thickness of 1,400 feet, as measured on Rundle Mountain, and the writer measured a section at the rockwool plant at Gap Lake a few miles east and found it to be 1,489 feet thick. The formation thins eastward, being about 800 feet at the front range of the Rocky Mountains, 20 miles or more to the east.

The rockwool plant mentioned above utilized beds of calcareous shale that are present in the interval from 350 to 500 feet above the base of the formation.

Rundle Formation

This formation is cliff-forming and forms the precipices above the Banff formation on The Three Sisters, Mount Rundle, and Cascade Mountain. The formation is composed of relatively resistant limestone and dolomite. It has been divided by Clark (1949, p. 628) into two members, a lower member 1,100 to 1,300 feet thick, and an upper member 600 feet thick. The lower member consists mainly of crystalline limestone; the upper is a succession of argillaceous limestone, cherty limestone, sandstone, shale, and dolomite. The section measured by Warren (1927, p. 28) on Tunnel Mountain is 2,400 feet thick. Thus the formation thins eastward rather markedly.

Rocky Mountain Formation

This formation is well exposed at the top of Pigeon Mountain in the map area. There it is 600 to 625 feet in thickness, and can be divided into three members. The lower member, 120 feet thick, is largely medium grey, thinly bedded dolomite, cherty and sandy in places; the middle member, 350 feet thick, consists of white, pinkish weathering quartzite; and the upper member, 150 feet thick, consists of chert and dolomite. The chert bed, about 50 feet thick, contains large geodes lined with quartz crystals. The uppermost 50 feet is concealed there, but is probably composed of dark grey, cherty quartzite that was observed elsewhere at this horizon. Warren (1927, p. 35) gives a thickness of 700 feet for the formation in a section measured on Tunnel Mountain, and Clark gives a thickness of about 275 feet in the vicinity of Exshaw. The formation is absent at Moose Mountain southeast of Exshaw. The age of the lower part of the formation is definitely Pennsylvanian, and, in places at least, the upper part is considered by Warren to be Permian.

The formation is exposed at the west end of Lake Minnewanka, in the vicinity of the Calgary Power Ltd. dam. In fact, this earth dam blocking the west end of the lake utilizes the Rocky Mountain formation as a foundation. The contact of the Rocky Mountain formation and the overlying Triassic Spray River formation is exposed at the western base of the dam.

Spray River Formation

The Spray River formation consists of dark grey, reddish-brown weathering siltstone, dolomitic in the upper part, and some shale and dolomite. The formation is thinly bedded except at the top, where massive dolomitic siltstones are present. The basal beds are usually soft shales. The age of the formation, based on fossil evidence, is Lower Triassic. A thickness of 600 feet is assigned to this formation in the Canmore area, based on a section measured a few miles southeast, along Evans-Thomas Creek (Crockford, 1949, p. 19). Warren gives a thickness of 1,800 feet on Sulphur Mountain a few miles westward. Eastward, in the Moose Mountain area, the formation is absent, and therefore, a rapid thinning eastward is evident.

Fernie Formation

The best complete section of Fernie within the area is exposed on the eastern slope of Mount Allan, a few miles southeast of Canmore. There the formation is 1,100 feet thick (Crockford, 1949, p. 24). It consists of five lithologic units, which in descending order are: 170 feet of sandstone; interbedded sandstone and shale ("passage beds") having a thickness of approximately 190 feet; 375 feet of dark grey shale containing large concretions at the base; 120 feet of hard, black, fine grained sandstone; and at the bottom 360 feet of black, fissile shale containing an extremely fossiliferous limestone band 90 feet above the base. Fossils found in the formation in the general area indicate an age range of Upper-Lower to Middle-Upper Jurassic. Within the map area the formation is poorly exposed, but some exposures can be seen along Cascade River. Very few fossils have been found.

Kootenay Formation

The Kootenay formation is important for coal, and the towns of Canmore, Anthracite, and Bankhead were founded upon this commodity. In the Canmore basin commercial coal seams are found in the lower 2,600 feet of the formation. The best section of the Kootenay is on the east face of Mount Allan, a few miles southeast of the map area. There a thickness of 3,400 feet was measured (Crockford, 1949, p. 32). The formation can be divided into four members which are: an upper member containing numerous conglomerate beds, and having a thickness of 200 to 600 feet; a sandstone member which is predominently sandstone and shale, measuring 1,800 feet in thickness; the coal measures, which are 1,150 feet in thickness, and contain numerous coal seams along with shale and sandstone; a basal sandstone member about 50 feet in thickness that is apparently gradational into the underlying Fernie.

Outcrops of Kootenay shale and sandstone occur in places along Cascade River, and they can also be found in gullies that lead down the lower slopes of the mountains on the west wall of the Bow Valley. Exposures can also be seen along the new highway from Anthracite westward.

Blairmore Formation

The Blairmore is not thought to be present within the area, but small exposures of it are present on the tops of some ridges a few miles south and east, and about 1,000 feet of the formation is present at the top of Mount Allan (Crockford, 1949, p. 47). There the formation consists of massive basal conglomerate beds overlain by interbedded sandstone, coarse sandstone, conglomerate, and red, grey, green and maroon shales.

STRUCTURAL GEOLOGY

REGIONAL STRUCTURE

A study of the structural geology of southwestern Alberta shows that the foothills and mountains are part of a vast anticlinorium, which has its apex approximately at the British Columbia-Alberta boundary. The component anticlines of this structure are in most cases faulted and may have been subsidiary folds. The faults are, as a rule, west dipping, and many fault blocks partly override the next block adjacent on the east. The vertical displacement of some faults is many thousands of feet. Erosion has reduced the anticlinorium to a series of parallel and sub-parallel fault ridges and ranges which have a general southeast-northwest trend. The exposed strata in general are progressively older westward until on the Continental Divide, which is also the British Columbia-Alberta border, Precambrian rocks are exposed. On the outer margin, that is on the eastern limit of the disturbed belt or foothills, the Cretaceous Edmonton rocks are exposed.

The ability of rocks to resist deformation imposed on them by the enormous pressures of the Rocky Mountain orogeny varied greatly. The more resistant beds are the thickly bedded Palaeozoic limestones and dolomites that make up much of the rocks of that era. These competent strata tend to form the most prominent ridges and mountains, and the Mesozoic rocks, being composed principally of shales and sandstones and some conglomerates, are less competent and occupy the topographically low areas. In places the conglomerates that have been developed in the Blairmore formation are competent enough and ressistant enough to erosion to produce mountain masses. The Mesozoic beds are in many places intricately folded, faulted and crushed.

Most rock formations of the Alberta plains and foothills thicken westward, so that their absence in mountains and plains can be attributed to erosion following the uplift of the Rocky

Mountains. Thus, in the mountains, where Palaeozoic strata alone are exposed, some 20,000 feet or more of Mesozoic beds have been removed, and in the vicinity of the Continental Divide, where Precambrian is exposed ,another 10,000 feet or more of Palaeozoic rocks have been eroded.

LOCAL STRUCTURE

The Canmore coal basin consists of an inlier of Mesozoic rocks comprising the Spray River, Fernie, and Kootenay formations. The strata of the inlier and the adjacent Palaeozic rocks have been foldeded into an asymmetric syncline. The west limb of the syncline is steep, and in places is overturned, and furthermore is truncated by a major fault. The east limb is broader, less steep, and less complex.

The synclinal structure of the Canmore area is shown in the three cross-sections of Figure I. The syncline is well shown at the surfcae along strike a few miles south, in Mount Allan, and in the ridges flanking it on the north, and can be seen from the Trans-Canada Highway. The massive Blairmore conglomerates present in the upper part of the structure accentuates its outlines. Rock formations from Kootenay to Palliser are present in the east limb, but only Kootenay beds are exposed in the west limb, the lower formations being overridden by Palaeozoic formations that comprise the Three Sisters-Rundle-Cascade thrust block. That formations older than Kootenay are present at depth on the west limb of the syncline is indicated by slices of Rocky Mountain quartzite, Triassic, and Fernie shales that have been dragged up along the fault and are present along the fault plane. The west limb of the syncline has suffered most, being crushed, contorted, and faulted in proximity to the Palaeozoic thrust block. Deformation decreases away from the major fault and towards the synclinal axis.

In the north part of the map area the syncline is not so evident (Cross Section A-A', Figure I), as its west limb has been truncated by the Rundle-Cascade fault. However, farther north the synclinal structure is again very evident at the surface (Dowling, 1907).

The Rundle-Cascade fault on the west has brought Devonian rocks over Kootenay, and has a displacement of 8,000 feet or more. The surface trace of the fault is sinuous in the mountains owing to differential erosion of the limestone, and also to the inclination of the fault plane. The latter dips from 30 degrees to 75 degrees west in several places where it was observed in the south part of the map area, and in the Kananaskis area adjacent to the south. The average dip of the fault plane is about 45 degrees west, and where it is well exposed was observed to be undulating. The rocks above and below show evidence of stress, the Palliser limestone above the fault plane being brecciated or tightly folded, and the underlying Kootenay complexly folded, overturned or crushed.

All observed faults dip west at varying angles. Several transverse faults are present along strike in the region to the south, and some may be present in the map area, but if so they are obscured by the thick mantle of alluvium and glacial drift.

ECONOMIC GEOLOGY

COAL

Mineable coal seams occur in the Kootenay formation and have been worked on the east flank of the syncline. At Bankhead they are apparently confined to about 1,100 feet or so of the formation (Dowling, 1914, p. 45), and in the Kananaskis area on the south they are present only in the lower 1,200 feet. The thickness of the seams in the Canmore basin is as great as 19 feet. In the Bankhead area fourteen seams more than four feet thick have been reported. The coal is semianthracite and too hard for railway use. Some 1,000 tons of coal and 300 tons of briquets were produced daily when the mine operated. In the mine at Anthra-

cite, five seams were worked. The pillars in this mine were pulled in 1904. At Canmore, twelve seams are workable, but only eight have been mined. The coal produced there is steam coal or low volatile bituminous.

PHOSPHATE

Phosphate occurs in two zones within the map area, one at the top of the Rocky Mountain quartzite, and the other at the base of the Fernie. Tests of samples from the zone in the Rocky Mountain Quartzite yielded only a trace of phosphate. Although shales in the Fernie tested higher in phosphate, they also are too low to be commercial.

BUILDING STONE

Dolomitic shales of the Spray River formation are used extensively as building stone at Banff. These rocks have great strength, even jointing, and regular bedding properties, which make them suitable for construction purposes. In the Canmore basin there are few exposures of Spray River, and any outcrops observed there have considerable cover, and in addition are not suitably situated for quarrying purposes.

GRAVEL

Gravels of glacial and recent origin are very abundant in the valley and are used extensively for road metal and for other construction purposes.

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THE GHOST RIVER NEAR BOW VALLEY

REIN deWIT[1]

INTRODUCTION

A conspicuous band of buff, ochre, and reddish coloured beds, called the Ghost River formation, can be noticed along the entire eastern mountain front near Banff and Jasper National Parks. The age of this formation has been debated frequently and an attempt is made in the following notes to assemble further evidence to establish its position in the stratigraphic column.

The name Ghost River formation was established by C. D. Walcott in 1921. Walcott's latest description of the formation is as follows: "Thin bedded and shaly, buff-coloured magnesian limestones, 285 feet in thickness, which are superjacent to the Middle Cambrian limestones of the Ptarmigan formation, and subjacent to massive Devonian limestones" (Walcott 1928, p. 210).

The "Middle Devonian limestones" were called the Messines formation by Walcott (1924), but they are at present known as the Fairholme group (Beach 1943, McLaren 1955), and are generally considered to be of Upper Devonian age. Walcott noticed that the age of the beds underlying the Devonian differs greatly between the Main Ranges and the eastern mountain ranges. He also believed that he had found equivalents of the Ghost River at the base of the Devonian west of the type locality and logically concluded that the Ghost River represents basal Devonian, separated from the underlying beds by a major unconformity. However, a review of his Ghost River equivalents (Walcott 1928, pp. 210, 211, 272, 282) shows that these are dissimilar from the original type and that probably they form part of the Fairholme.

The typical Ghost River lithology of the Front Ranges is not found at the base of the Devonian farther west in the Rocky Mountains.

Storey (1955) tried to revive Walcott's idea by suggesting that the Ghost River could be the basal clastic unit of the westward transgressing late Devonian seas.

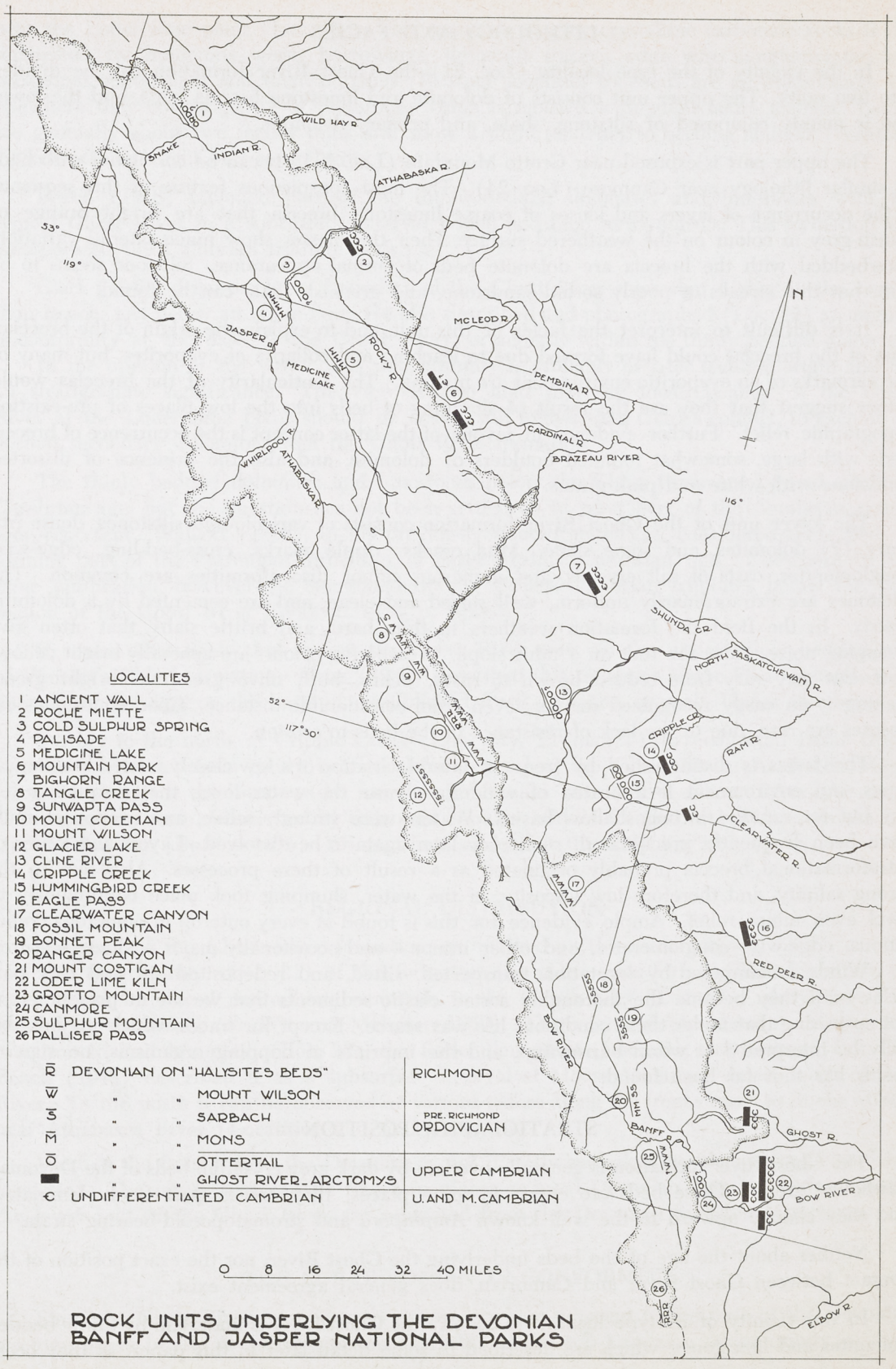
The most popular concept regarding the age of the Ghost River formation is that it probably belongs to the Middle Devonian, and that it could be equivalent to part of the Elk Point group (Clark 1949, Webb 1951, Andrichuk 1951, Harker, Hutchinson, and McLaren 1954). The Ghost River lithology is indeed the same as that of many zones in the Elk Point. It reflects similar conditions during sedimentation.

Near the headwaters of the Saskatchewan and Bow Rivers is found a quartzitic sandstone unit, called the Mount Wilson quartzite, and it has been suggested that this could be equivalent to the Ghost River formation. Walcott (1928) pointed out that both formations occur at the base of the Devonian, but fossils collected subsequently proved that the Mount Wilson is late Ordovician or Silurian in age (deWit and McLaren 1950, Severson 1950). If the Ghost River were of the same age, it would mean that it is separated by unconformities from the overlying Devonian and from the underlying Cambrian at the type locality.

Beach (1943), and also MacNeil (1943), suggested Cambrian age for the Ghost River, because of Cambrian trilobites that were found at the base of the formation. Clark (1949) questioned the validity of Beach's argument, and concluded that the Cambrian trilobite beds should be excluded from the Ghost River formation. De Wit (1956) arrived by different reasoning at the same conclusion as Beach regarding the age of the Ghost River.

[1] Sohio Petroleum Company.

Many geologists assisted with information, ideas, and help in the field. The writer wishes to thank particularly the following persons: H. R. Belyea, F. G. Fox, H. Halbertsma, G. E. Hargreaves, A. M. Patterson, F. K. North, and H. Woodward.



ROCK UNITS UNDERLYING THE DEVONIAN
BANFF AND JASPER NATIONAL PARKS

LITHOLOGY AND FACIES

In the vicinity of the type locality (Loc. 21) the Ghost River formation can be divided into two units. The upper unit consists of dolomite and limestone breccia beds, and the lower one is mainly composed of siltstone, shale, and primary dolomite.

The upper part is exposed near Grotto Mountain (Loc. 23). It can be correlated with beds of similar lithology near Canmore (Loc. 24). The most conspicuous feature of this sequence is the occurrence of layers and lenses of coarse limestone breccia that are bright orange or bluish-grey in colour on the weathered surface. Their thicknesses show much laterial variation. Interbedded with the breccia are dolomite beds of normal appearance. Siltstone seems to be rare, but thin streaks of poorly sorted sandstone, and greenish shale can be found.

It is difficult to interpret the facies of this unit, and to explain the origin of the breccias. Part of the breccias could have formed due to leaching and collapse of evaporites, but many of the earmarks of an evaporitic environment are missing. The lenticularity of the breccias would rather suggest that they are the result of slumping of beds into the low places of pre-existing topographic relief. Further evidence in favour of the latter concept is the occurrence of breccia beds with large, somewhat rounded boulders of dolomite, and also the presence of ill-sorted sandstone with white and pink grains.

The lower unit of the Ghost River formation consists of varicoloured siltstones, dense primary (?) dolomites, and some shale. Mud cracks, ripple marks, cross-bedding, edge-wise conglomerates, casts of salt crystals, and numerous minor disconformities are common. The siltstones are extraordinarily uniform, well sorted and clean, and are cemented by a dolomitic matrix. In the field the formation weathers in thin, hard, and brittle slabs, that often give a ringing noise under the foot on a talus slope. Weathering colours are generally bright yellow-buff, but may vary from reddish-brown to rusty, ochre, buff, olive green, to bright green, making it an easily recognized marker, even from considerable distance. Good continuous exposures are rare, due to the lack of resistance of the beds to erosion.

The facies is distinguished by frequent lateral variation of a few closely related lithological types. An environment is indicated of wide flats, near the water level, that frequently fell dry but for rapidly shifting shallow basins. Waters were strongly saline, and evaporites must have been frequently precipitated, sooner or later again to be dissolved. Layers and lenses of intraformational breccia probably originated as a result of these processes. Also due to the strong salinity, and therefore low viscosity, of the water, slumping took place continuously to level even minor relief. Ample evidence for this is found at every outcrop in numerous crenulations, edge-wise conglomerates, and other minor – and occasionally major – slump features.

Winds, unhampered by vegetation, transported, sifted, and redeposited silt and clay particles until they became the thoroughly sorted clastic sediments that we see at present. It is not surprising that under these conditions life was scarce. Except for traces, which may doubtfully be interpreted as worm burrowings, and the imprints of hopping organisms, no sign of fossils has thus far been found.

STRATIGRAPHIC POSITION

The Ghost River formation is generally overlain by dark grey crystallin beds of the Devonian Fairholme group. These beds are cherty in some places; they are in part finely laminated, and they change upward to the well known *Amphipora* and stromatoporoid-bearing strata.

Neither about the age of the beds underlying the Ghost River, nor the exact position of the contact between Ghost River and Cambrian, does general agreement exist.

In the vicinity of its type locality (Loc. 21) the Ghost River is underlain by thinly bedded dolomites and limestones, which are described in some detail later in this paper, as they occur

near the Loder lime plant (Loc. 22). This sequence of grey crystalline carbonate rocks is distinguished by numerous worm burrowings, dolomitic tracery, edge wise conglomerates, and occasional oolitic beds and fossil horizons. In some localities the beds are all dolomitized, but elsewhere they consist partly of limestone, which is mottled with vivid ochre colours. Layers are generally about two inches thick and show a slight tendency to become nodular. Weathering colours are bright buff to dull grey.

Beach (1948) included part of the thinly bedded dolomites and limestones with the typical Ghost River in a subsurface interval which he called formation D. This formation also incorporated the Cambrian trilobite beds.

Clark (1949) drew the lower boundary of the Ghost River somewhat higher in the section than Beach, just below an oolite bed. He also described and photographed (Loc. 22) an angular unconformity at the base of the Ghost River, or actually within the thinly bedded dolomites.

In the opinion of the writer, this unconformity is probably of later tectonic origin and has no stratigraphic significance. The view is also held that the lower contact of the Ghost River at the Loder lime plant should be drawn still higher than Clark's contact, to exclude all normal secondary dolomites from the Ghost River formation.

The thinly bedded dolomites and limestones below the Ghost River are beyond doubt of Cambrian age, but the question has not been settled as to what part of the Cambrian system they represent. Walcott (1928), in his previously quoted statement, considered these beds as forming part of the Ptarmigan formation, of early Middle Cambrian age. Elsewhere in the same publication, however, he mentioned finding Upper Cambrian trilobites below the type section of the Ghost River (Walcott 1928, p. 262).

It seems most likely that in fact the Ghost River rests on the upper thinly bedded part of Walcott's Eldon formation. Deiss (1939) described this sequence as the Pika formation, and determined the age, on the basis of unpublished fossil evidence, as early Upper Cambrian.

Farther to the north, at Cripple Creek (Loc. 14), Erdman (1946) collected basal Upper Cambrian trilobites from thinly bedded dolomites below the Ghost River. At Roche Miette (Loc. 2) abundant trilobites can be found in limestones just below Ghost River-type beds. These trilobites were determined by Raymond once as Middle Cambrian, and later as the late Upper Cambrian (Burling 1955). It is not impossible that the truth lies in between.

REGIONAL DISTRIBUTION

Outcrops of the Ghost River formation are marked on the accompanying map.

The type locality (Loc. 21) of the formation lies at the main fork of Ghost River. To the south it can be traced around one mountain to the Devil's Gap (Loc. 21), where it was examined by the writer (de Wit and McLaren 1950). There is no doubt about its further continuation to End Mountain (Loc. 22), the Loder lime plant (Loc. 22), and Exshaw (Loc. 23). Beach (1943) described it as a subsurface interval at Moose Monutain dome, south of Bow River. To the north it can be observed at various places along the front ranges to Roche Miette, near Athabasca River (Localities 2, 6, 7, 14, and 16).

West of the front ranges the Devonian is not directly underlain by the entire Ghost River formation. The upper part can be found in places as basal Devonian unit, but beds similar to the lower unit of the Ghost River are separated from the Devonian by other formations.

THE SUB-DEVONIAN UNCONFORMITY

Since the Ghost River is apparently not everywhere adjacent to the base of the Devonian, we may pause briefly to investigate the character of the sub-Devonian unconformity.

Many authors have noted the magnitude of the unconformity between the Devonian and a variety of underlying older beds, ranging in age from Silurian to Cambrian (Walcott 1927, 1928, Beach, 1943, North and Henderson 1954). The most systematic and comprehensive study in this respect was the one by Harker, Hutchinson and McLaren (1954).

On the accompanying map a number of data have been compiled. Nomenclature has been kept as simple as possible, for the sake of clarity, by omitting the many equivalents, synonyms, and finer subdivisions that could be taken into account.

It appears that on strike with the upper Bow River Valley the Devonian Fairholme formation is underlain by young Ordovician beds. The "Halysites beds", of Richmond age, are somewhat local in their present distribution and overlie the Mount Wilson quartzite. At Glacier Lake (Loc. 12) Walcott designated the beds underlying the Devonian as the Sarbach formation. However, it appears from his description that he did not study the actual contact, and it is not impossible that the Mount Wilson quartzite, perhaps including the Richmond, may be present. Between Banff and Clearwater Canyon (Loc. 17) the Devonian is underlain by Sarbach, which decreases in thickness southward so that it is missing in the southern part of the Sawback Range, where the Devonian immediately overlies the Mons. At Sulphur Mountain (Loc. 25) we find quartzite beds which tentatively may be considered equivalent to the Mount Wilson quartzite.

Near Jasper, at the Palisade (Loc. 4), the most westerly exposure of the sub-Devonian unconformity shows the Upper Devonian Flume formation resting on Mons equivalent. A similar situation probably exists just east of Medicine Lake (Loc. 5). At the Cold Sulphur Spring (Loc. 3) the Devonian rests on dolomites that have been designated in the past as "beds of undetermined age". Beds of similar lithology and stratigraphic position are present near the mouth of the Cline River (Loc. 13), at Hummingbird Creek (Loc. 15), and also near Canmore (Loc. 24) on the road to the Spray Lakes. At the latter two localities they are underlain by "Ghost River". The "beds of undetermined age" have a superficial similarity to the Fairholme and have, therefore, been included by some geologists in the Devonian. These dolomites are dense and dark grey or light grey in colour. Some reddish or ochre mottling can be noticed in places and they are invariably unfossiliferous with the exception of rounded algal balls with concentric layers. The contact of these beds with the overlying Devonian may be hard to place. At Hummingbird Creek the uppermost part of the "beds of undetermined age" is discoloured on the weathered surface and has been mistaken by some for Ghost River, which actually is present at the base of this section. It appears most probable that the "beds of undetermined age" belong to the Upper Cambrian Ottertail formation. This is a widespread and largely unfossiliferous carbonate unit of the Rocky Mountains, which is separated, near Bow Valley, from the brightly coloured Arctomys formations by the relatively thin and soft Bosworth formation (Walcott 1928).

In the front ranges the Upper Devonian is underlain by the Ghost River formation.

AGE OF THE GHOST RIVER FORMATION

Thus, the general lineation of formations at the sub-Devonian unconformity appears to form a pattern, with younger formations to the west and increasingly older beds to the east underlying the Devonian. As it is rather improbable that the Upper Cambrian and Ordovician would all be absent to the east due to non-deposition, it can be assumed that there is an angular unconformity between the Devonian and the underlying beds, as depicted on cross-section I, with the angle of discordance, of course, much smaller than shown.

This relationship was recognized and expressed by North and Henderson (1954, p. 66). The unconformity is somewhat similar to the one separating the Devonian from the underlying

11815 Jasper Ave
Edmonton.
June 13 1958.

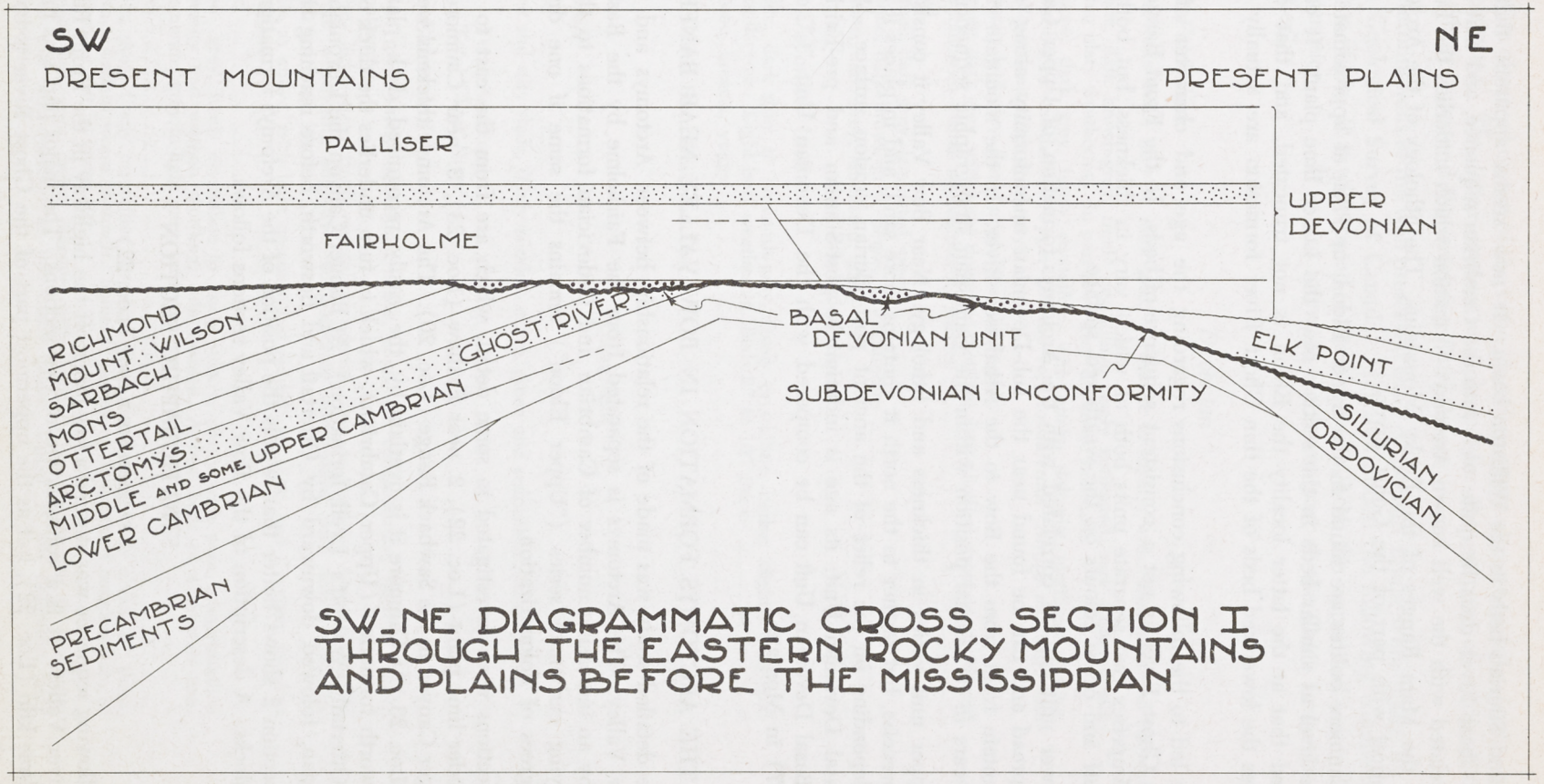
Hi
Happy Fathers Day -
sorry the picture
is not on the scale
of some - If you
check in your vault
there's a surprise for
you (?)

Just got these last
night so forwarded them
right on. Will be talking
to you soon

Love

Helen

P.S. I have included everything & you can judge what to do. Was the needle recently changed.



SW-NE DIAGRAMMATIC CROSS-SECTION I THROUGH THE EASTERN ROCKY MOUNTAINS AND PLAINS BEFORE THE MISSISSIPPIAN

Ordovician and Silurian beds in the Williston basin. It now seems apparent that the lower unit of the Ghost River does fit quite well into the Cambrian sequence, and that it can logically be correlated with the well known Arctomys formation which underlies the Bosworth and Ottertail in the Main Ranges of the Rocky Mountains. The lithology of the Arctomys formation is identical with part of the Gohst River.

Near Canmore oolites are found in the upper Eldon, or Pika, at approximately the same stratigraphic level as similar beds in the section near the Loder lime plant. It can therefore be concluded that at the latter locality the Eldon is not truncated, and that even in the Front Ranges the lower red beds of the thin Ghost River formation are actually part of the Arctomys.

We are led to the following conclusions regarding the age and character of the Ghost River. The Ghost River is not a consistent sequence of beds. In the Front Ranges near Bow Valley it comprises two separate units both of which vary in thickness, but both show conspicuous buff and ochre colours on the weathered surface.

The lower unit can be correlated with the Arctomys formation, of Upper Cambrian age. It is widespread and can be found near the sub-Devonian unconformity along most of the Rocky Mountain front from the Bow to the Athabasca River. In the mountain ranges to the west it appears in its normal position within the Cambrian stratigraphic sequence.

The upper unit varies in thickness and lithology. Near Bow Valley it consists mainly of limestone breccias, but farther to the north it contains more sand, and in places it is altogether absent — depending on the relief of the ancient post-Silurian erosion surface. We may call this the Basal Devonian Unit; its age is indefinitely post-Silurian and pre-Fairholme. Probably the Basal Devonian Unit can be compared with the Devonian Unit "C" of Sloss and Laird (1947) in Montana.

THE ARCTOMYS FORMATION IN BOW VALLEY NEAR BANFF

A more detailed study was made of the relationship between Arctomys and Ghost River in the Bow Valley. The Arctomys is separated from the Fairholme by the Basal Devonian beds, and by an increasing number of Cambrian and Ordovician formations to the west, but the underlying carbonate series ("Upper Eldon") remains the same if one disregards the varying degrees of dolomitization.

Four sections were investigated in some detail, which are from the east to the west: 1. near the Loder lime plant (Loc. 22), 2. near Exshaw (Loc. 23), 3. near Canmore (Loc. 24), and 4. Ranger Canyon in the Sawback Range (Loc. 20). The Arctomys thickens westward from Loc. 22 to Loc. 23. At Canmore it is overlain by the easily recognized dark platy dolomites of the Bosworth formation (Upper Cambrian), which in turn underlies the thick oolite beds of the basal Ottertail (Walcott's Lyell formation). At Ranger Canyon the Devonian is underlain by Ordovician, folowed downward by Ottertail and Bosworth, before reaching the Arctomys.

Cross-section 2 shows better than words the position of the Arctomys formation in consecutive fault blocks. A description of the Bow Valley sections follows.

STRATIGRAPHIC SECTION

FAIRHOLME RANGE (LOC. 22)

The following sequence was studied a few miles off the highway in the Front Range north of the Bow River Valley. It is a combination of two sections. The major part was measured near the Loder lime kiln (Loc. 22), but as the uppermost part of the Ghost River is covered at this

locality, a section observed on top of the same mountain range about two miles farther to the north has been substituted. The latter section was chosen for the purpose of studying the contact between the Ghost River and the overlying Fairholme.

Fossil determinations of the well preserved basal Devonian fauna were made by D. J. McLaren of the Geological Survey of Canada. McLaren added the following comment: "This is a normal Flume fauna. It is widespread in the Rockies in both the upper and lower members of the Flume formation . . . . It is also found in the lower part of the Cairn formation at widely spaced localities".

Devonian

Basal Fairholme

	Thickness
Dolomite beds, grey to dark grey, crystalline to sugary, with *Amphipora* and stromatoporoids	
Dolomite, dark brown-grey, finely crystalline, finely laminated, rare scattered silt, thin platy weathering. In part dark grey dolomitic limestone	9'2"
Limestone, dark grey, finely crystalline, with brown dolomite mottling, massive, bluish-grey weathering. Upper 10" are very fossiliferous: *Atrypa multicostellata Allanaria minutilla* Crickmay?	3'10"
Limestone, dark grey, finely crystalline, thinly platy	2'6"
Limestone, dark grey, with some dolomitic mottling, few silicified stromatoporoids and brachiopods visible on weathering surface	3'1"
Covered	3'6"
Limestone, dark grey, laminated, platy	1'6"
Limestone, dark brown-grey, dense, unfossiliferous	2'1"
Limestone, dark grey, laminated, platy	2'3"
..... sharp lithological change	

Basal Devonian Unit

Dolomite, dark grey to brownish-grey, finely crystalline, dense, slightly silty and argillaceous. Light buff weathering. Beds 2" to 10" thick	5'3"
Limestone, breccia, vuggy	1'1"
Total Basal Devonian Unit	6'4"

Cambrian

Arctomys

Covered	10'
Siltstone and silty shale, thinly bedded, ochre, green and reddish-brown colouring	15'
Total Arctomys	25'
Total Ghost River	31'4"

Upper Eldon or Pika

Dolomite, grey, finely crystalline, dense, edge-wise conglomerate, buff to orange weathering	5'
Dolomite, light grey, finely crystalline, dense, thin to medium bedded, mainly ochre weathering edge-wise conglomerate interbedded with softer dolomite, with scattered silt	11'
Dolomite as above, with light greenish and reddish mottling, and irregular siliceous stringers	4'6"
Covered	13'
Dolomite, grey, finely crystalline to finely sugary, partly with poor intercrystalline porosity and maroon mottling, thin bedded. A few beds of edge-wise conglomerate, grey to light grey, buff weathering, up to 4" thick	8'
Covered	3'6"
Dolomite, grey, finely crystalline, brownish-buff weathering, beds about 2" thick, with abundant worm channels. Some 4" layers of dolomitized conglomerate of limestone grit in lower 10'	45'
Limestone, dark grey, dense, massive, with dolomitic tracery, similar to Cambrian beds that are quarried at the Loder plant. Upper 7' are dolomitic, buff weathering	23'

	Thickness
Limestone, dark grey, dense, weathered surface blue-grey with ochre mottling, oolitic band	33′
Covered interval, fragments of trilobites and inarticulate brachiopods in talus	10′
Limestone, dolomitic, dark grey, dense, numerous worm channels, buff to ochre weathering, beds about 1″ thick, with thin dolomitic stringers and beds	25′6″
Covered	50′
Limestone, grey to dark grey, coarse dolomitic tracery, dark grey and ochre mottling on weathered surface. Beds 2″ thick, with faint impressions of thin worm channels (?)	41′
Limestone, argillaceous, grey with greenish and reddish mottling, in part interformational conglomerate with rounded fragments up to ½″	4″
Covered	3′
Limestone, argillaceous, light grey to buff, thinly bedded, soft	4″
Limestone, grey, dense, coarse tracery and mottling, dark grey and buff weathering, beds 2″ to 6″ thick	9′6″
Covered	2′6″
Limestone, grey to buff-grey, crystalline, limestone grit with veinlets and specks of white calcite and green shale	6″
Total Upper Eldon	288′8″

Lower Eldon

Limestone, grey to dark grey, finely crystalline light grey weathering, beds 6″ thick in part massive	76′
Limestone, grey to dark grey, finely crystalline, with dolomitic tracery, massive.	

GROTTO MOUNTAIN THRUST BLOCK (LOC. 23)

The section was measured at the foot of Grotto Mountain, one-half mile north of the highway. The Arctomys is almost completely exposed in the second ravine west of Exshaw.

Devonian

Fairholme

Dolomite, dark grey, crystalline to sugary, fossiliferous Dolomite, grey, finely crystalline, massive to platy weathering	15′

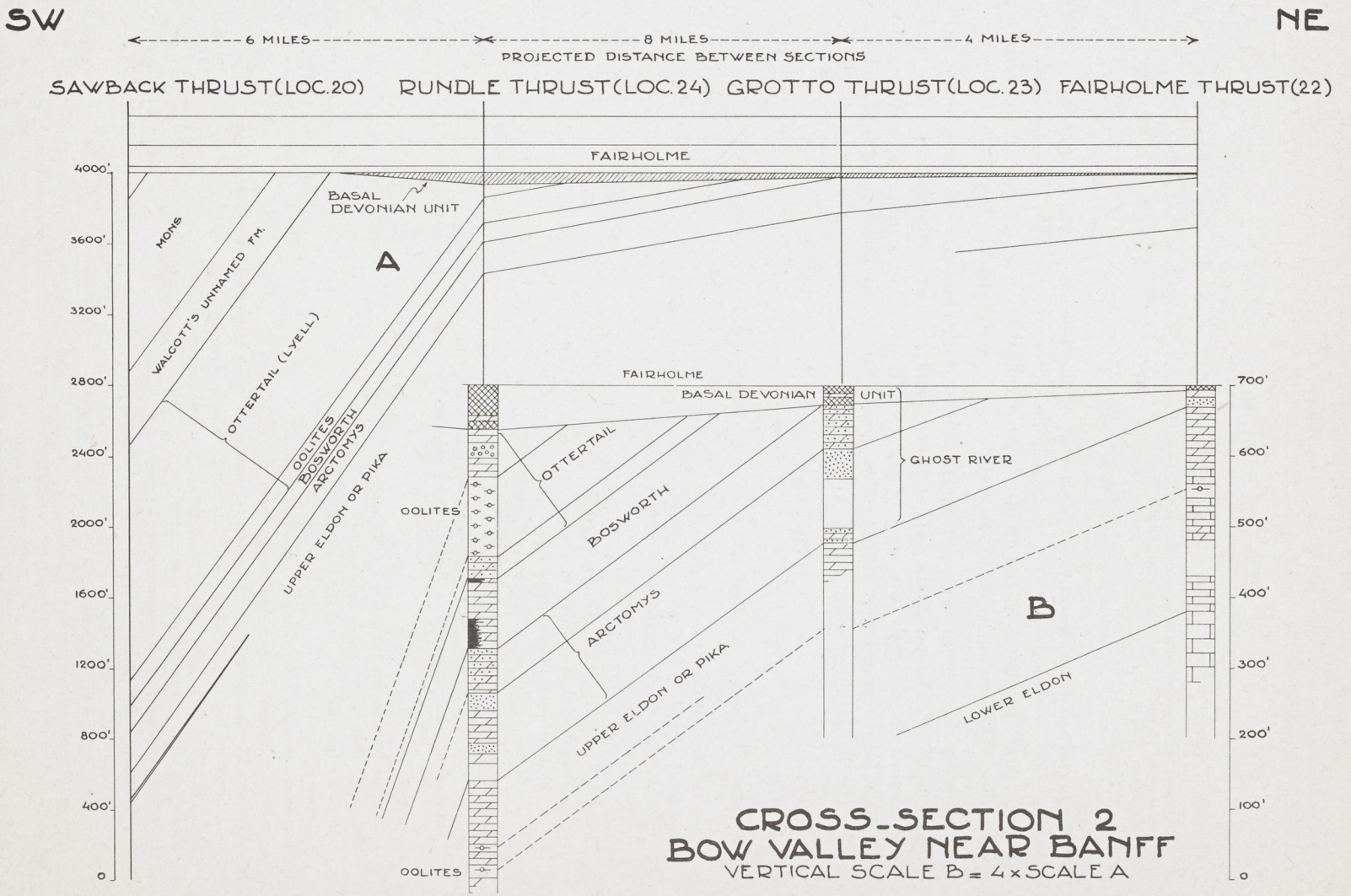
Basal Devonian Unit

Limestone, coarse breccia, with angular fragments of grey and light brown limestone up to 2″ in diameter, widely scattered in matrix of orange coloured vuggy limestone	3′
Dolomite, calcareous, light grey, finely granular, rich in tiny secondary quartz crystals, finely laminated, grey platy-weathering. Beds alternating with a few layers of limestone breccia of varying thickness	27′
Total Basal Devonian Unit	30′

Cambrian

Arctomys

Dolomite, silty, grey to buff, finely crystalline, bedded, grey-buff weathering, interbedded with few silty beds	15′
Dolomite, grey, crystalline, and siltstone, buff, thinly bedded, buff weathering	20′
Shale, slightly dolomitic, finely silty, dark grey to black	6″
Dolomite, in part silty, grey-brown to buff, finely crystalline, thin bedded	25′
Shale, silty and dolomitic, reddish-brown, occasionally greenish, rubbly weathering, some cross-bedding	42′
Covered	70′
Shale, silty, reddish-brown, blocky weathering	5′
Dolomite, buff, finely crystalline, dense, edge-wise conglomerate	1′
Siltstone, slump breccia	1′6″
Dolomite, silty, light buff-grey, finely crystalline, dense, pale greenish and reddish in part	5′
Dolomite, buff-grey, finely granular, finely pyritic, buff weathering	3′
Dolomite, blue-grey, dense, massive	3′



CROSS-SECTION 2
BOW VALLEY NEAR BANFF
VERTICAL SCALE B = 4 × SCALE A

	Thickness
Shale, silty, green, with lenses of cross-bedded siltstone	1′
Dolomite, blue-grey, dense, massive	1′
Total thickness Arctomys	193′
Total thickness Ghost River	223′

Upper Eldon ?

Dolomite, calcareous, dark blue-grey, well bedded, beds 2″ to 5″ thick; bedding surface in upper part somewhat shaly.

MOUNT RUNDLE THRUST BLOCK (LOC. 24)

In a steep gully or run-off, some six miles west of the Bow River near Canmore, a well exposed section can be examined from the Fairholme down through the basal Devonian, Ottertail, Bosworth, and Arctomys, to the thinly bedded dolomites that are tentatively referred to as Upper Eldon. The section is easily accessible north of the road to the Spray Lakes.

The following description begins at the first beds with abundant stromatoporoids that are most typical of the Fairholme group. Placing the boundary between the Fairholme and the Basal Devonian Unit is largely a matter of choice. The two thin bands of light coloured limestone that have been incorporated, in the following section, with the Fairholme, are certainly unusual for the Fairholme group.

Devonian

Fairholme

	Thickness
Dolomite, dark grey, crystalline to sugary, with abundant stromatoporoids, heavy bedded.	
Dolomite, grey to dark grey, crystalline, bedded	13′
Limestone, pinkish buff, finely crystalline, in part finely slumped	1′6″
Dolomite, grey, finely crystalline to finely sugary	2′
Covered	6′
Limestone, pinkish buff, finely crystalline, dense, with many fine vugs	1′4″
Dolomite, grey, thin to medium bedded, grey weathering, with some brownish hematite staining — Fairholme type	40′
Dolomite, dark grey, finely crystalline to sugary, large vugs	1′
sharp change	

Basal Devonian Unit

Limestone, buff, red mottled, strongly disturbed, probably due to slumping	3′
Limestone breccia, orange coloured, cellular appearance, coarsely fragmental, with chunks up to 6″	3′
Covered	3′
Limestone breccia, orange coloured, as above	5′
Dolomite, dark grey, finely laminated	1′
Limestone breccia, soft, orange, fragments less than 1″	1′6″
Covered	5′
Limestone breccia, soft, orange, dolomitic	1′
Dolomite, blue-grey, dense, buff weathering	6″
Dolomite, breccia, grey, with red mottling, scattered vugs, fragments irregular, as if moved in half plastic stage, some slumped pockets of green shale	5′
Dolomite, light grey, buff weathering, finely crystalline to dense	1′6″
Sandstone, fine grained, light brown-grey	1″
Dolomite, argillaceous, or dolomitic shale, green-grey	6″
Dolomite, light grey, finely crystalline, dense, light buff weathering	3′
Covered	2′
Dolomite, light grey, as above	3′6″
Dolomite, argillaceous, or shale, dolomitic, buff to greenish weathering, with streak of coarse grained sandstone, dolomitic, grey-buff, poorly sorted, with coarse grains	6″
Breccia, ochre to pinkish buff, with grey fragments	2′
Dolomite, grey, finely crystalline, thinly bedded, buff weathering	5′
Dolomite, dark grey, finely crystalline, dense, with thin band containing bryozoa? — Fairholme type lithology	1′6″

	Thickness
Dolomite, steel grey, crystalline, dense, buff weathering, beds thin to medium, in part shaly, and with 3″ band of fine dolomite grit	9′
Breccia, coarse fragments, somewhat rounded, up to 18″, slumped	3′
Grit of limestone in dolomitic matrix	1′6″
Total Basal Devonian Unit	61′

Cambrian

Ottertail

Dolomite, grey buff, with much red mottling	3′
Dolomite, grey finely crystalline to crystalline, red mottling	19′
Dolomite, grey crystalline, consisting of tightly packed pisolites or algal balls the size of a pea, that are surrounded by almost white crystalline dolomite. Weathering colours are buff to grey-brown	19′
Dolomite, grey, red mottling finely crystalline, massive	20′
Dolomite, grey, red mottling, thinly bedded, ochre-weathering	5′
Oolitic dolomite, grey, crystalline, medium to thickly bedded	25′
Shale, slightly calcareous, buff-grey, with olive green tinge, soft, flaky	2′
Oolitic dolomite, grey, crystalline, alternating thin and thick beds, a few non-oolitic bands of dark grey dolomite	28′
Shale, olive green, flaky, with 1″ of red siltstone at base	1′
Dolomite, grey, finely crystalline to crystalline, dense, in part silty, sandy, and oolitic, thickly bedded, prominently weathering	60′
Siltstone, light grey, thinly bedded	1′
Dolomite, light grey, crystalline, dense, grey weathering, thickly bedded	5′
Dolomite, grey, finely crystalline, dense, alternating with 5′ bands of dolomite, silty, pale grey, thin-platy, rusty-brown weathering, with ripple marks	25′
Total Ottertail exposed	213′

Bosworth

Dolomite, slightly argillaceous, dark grey, finely crystalline, platy	3′
Dolomite, grey, finely crystalline, massive	2′
Dolomite, pale grey, finely crystalline, dense, finely laminated, some irregular sand streaks at the top	20′
Covered	9′
Dolomite, as above	2′
Dolomite, argillaceous, dark grey, in part silty, thin-platy, ochre to brown weathering	39′
Total Thickness Bosworth	100′

Arctomys

Siltstone, maroon, and dolomite, dense, thin-platy, ochre weathering	10′
Dolomite, silty, dense, grey to reddish-grey	10′
Siltstone, maroon to olive green, ochre weathering	17′
Dolomite, argillaceous, dark grey to black, platy	5′
Dolomite, silty, grey and maroon, platy, ochre weathering	23′
Siltstone, maroon, platy, thinly bedded, ochre weathering, with mud cracks and ripple marks	5′
Siltstone and primary dolomite, reddish-grey, platy, ochre weathering	20′
Dolomite, light grey to grey, finely crystalline to crystalline, reddish mottling, in part finely laminated on weathered surface	47′
Siltstone, dolomitic, dark grey, fine grained, dense, hard, ochre weathering	3′
Siltstone, maroon	1′
Siltstone, grey to greenish, platy, in part argillaceous, ochre weathering	9′
Dolomite, pale buff-grey, finely crystalline, dense, bright ochre weathering	14′
Covered	24′
Total Thickness Arctomys	188′

Upper Eldon or Pika

Dolomite, grey to dark grey, crystalline, thinly to thickly bedded, occasional edge-wise conglomerate, few oolite beds 4″ to 10″ thick 95′ and 127′ below the top	150′

SAWBACK RANGE (LOC. 20)

An excellent section is exposed at an altitude of approximately 9,000 feet near the head of the northeast branch of Ranger Brook. This stream can be reached by proceeding eastward from Highway No. 1 between mile posts 12 and 13 west of Banff. The section has been de-

scribed by Walcott (1928, pp. 264-268). Due to weather conditions the writer was unable to verify in detail the various thicknesses quoted by Walcott. The basal oolites of the Ottertail (Lyell) formation are similar to those at Canmore (Loc. 24). They are underlain by dark grey platy dolomites of the Bosworth formation, that are also identical with those at Canmore. The dark argillaceous dolomites of the Bosworth formation seem to indicate that conditions of sedimentation were somewhat similar to those under which the Arctomys was formed. It is not impossible that vertical, as well as lateral transition of the two formations will be found eventually. The Arctomys is quite similar to the major part of the Ghost River formation at Grotto Mountain, and decidedly less dolomitic than the Arctomys of Canmore. A rough measurement of the Arctomys at Ranger Canyon showed that the formation is at least 200 feet thick, or twice the thickness of 95 feet quoted by Walcott.

The Arctomys is underlain by thinly bedded Eldon, but below an estimated 150 feet of this was found another interval of silty beds with mud cracks, similar to the Arctomys, and with an aggregate thickness of 25 feet. This interval was not mentioned by Walcott. It is well exposed, and it bears no mark of faulting that would indicate a tectonic repetition of strata. The underlying thinly bedded dolomites are those of the upper Eldon.

The contact between Devonian and Ordovician strata was not examined by the writer. Walcott (1928, p. 265) observed "in places a dark arenaceous shale about 6 feet thick at the base of the Devonian". It is difficult to visualize this shaly bed as an equivalent to the Ghost River formation.

The following interpreted section was compiled after Walcott's description (Walcott 1928, pp. 265-267).

Devonian

	Thickness
..... disconformity	
Ordovician	
Sarbach	
Limestone, lead grey, cherty, thin to medium bedded	48′
Dolomite, dark grey, buff weathering, with annelid borings	76′
Total Thickness Sarbach	124′
Mons	
Limestone, grey, thinly bedded, with *Obolus* and trilobites	236′
Limestone, grey, interbanded with calcareous shales	750′
Total Thickness Mons	986′
Unnamed Formation	
Limestone, grey, hard, massive at the top, thinly bedded in lower part	310′
Limestone, grey, oolitic, rusty brown weathering	90′
Total Thickness Unnamed	400′
Cambrian	
Lyell or Ottertail	
Dolomite, grey, arenaceous, thin and thickly bedded, with a few bands of lead coloured dolomite	1,325′
Oolitic dolomite, grey, with partings of dolomitic shale	145′
Total Thickness Ottertail	1,470′
Bosworth	
Dolomite, dark bluish-grey, compact, with interbedded platy dolomite	165′
Arctomys	
Shale, silty, greenish-buff, thinly platy	9′
Siltstone, shale, and dolomite, thinly bedded, maroon, partly black, buff weathering, ripple marks, salt casts, and sun cracks	200′+
Total Thickness Arctomys	209′+

Upper Eldon or Pika

	Thickness
Dolomite, steel grey, dove grey weathering, thinly bedded	150′+
Siltstone and dolomite, vari-coloured, buff to ochre weathering	25′
Dolomite, grey, as above	

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THE PERMIAN ROCKY MOUNTAIN GROUP IN ALBERTA

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STATUS OF THE TERM ROCKY MOUNTAIN FORMATION

The "Rocky Mountain formation" of earlier reports from McConnel (1887) to Warren (1927) was a name in a lithologic sense for strata dominantly arenaceous and siliceous, at the top of the Palaeozoic succession in Alberta. This usage appeared to serve very well in the Banff and Minnewanka areas, since all of the strata involved were, in those days, regarded as Permo-Carboniferous.

Faunal data and relatively detailed study have more recently shown that in the type locality at Mount Rundle as well as in the section at Lake Minnewanka, this usage of Rocky Mountain proves to have combined under one name beds in part mid-Permian in age and in part late Mississippian, and to involve an unconformity embracing all of the Pennsylvanian and one-third of the Permian. Moreover, although the Permian part of the original Rocky Mountain formation maintains a general lithologic consistency wherever present in Alberta, the Mississippian (Chesteran) part is only locally dominantly arenaceous, being prevailingly carbonate in the south (Etherington formation) and dominantly argillaceous in the north (Stoddart formation).

It was doubtless as a consequence of this lateral change that Clark (1949) in the Canmore-Exshaw area, Douglas (1950) in the Oldman River area, and Raasch (1954) in Highwood Pass, consciously or unconsciously restricted the term Rocky Mountain to post-Mississippian beds. The ample Chesteran faunas found by the writer in Highwood Pass were traced northwestward into the arenaceous facies at Banff, as was the post-Chesteran unconformity with its associated lithologic characteristics.

The Permian and late Mississippian sequences having been differentiated, how then are they to be designated?

In current practice, the term Rocky Mountain has come to signify for Alberta geologists that part of the Palaeozoic section considered to be post-Mississippian (i.e. "Permo-Pennyslvanian", so-called). It seems, therefore, a most satisfactory procedure to restrict the term Rocky Mountain to the Palaeozoic beds that can be discrimininated as post-Mississippian, namely the Permian formations. Since the Rocky Mountain sucession as thus defined, has when fully developed, a thickness approaching 1,000 feet and since it lends itself to major and minor subdivision, it is further recommended that it be given group status, thus equating it with the underlying Rundle Group, which embraces the upper three fourths of the Mississippian.

When the Rocky Mountain group is thus defined, that is to say when the Chesteran beds originally included in it are excluded, it seems appropriate that these latter be incorporated in the Rundle Group and retain the name Tunnel Mountain, since that term had been applied to the beds of this age by both Warren and Beach.

In 1947, when H. H. Beach before the Alberta Society of Petroleum Geologists and Warren before the American Association of Petroleum Geologists independently proposed the term Tunnel Mountain, it was the current impression that they had proposed the same term for beds in different parts of the section, the one for late Mississippian, and the other for Pennsylvanian rocks. Subsequent developments have shown that inadvertently both had applied the name to beds of essentially the same age but different facies, namely the late Mississippian, Chesteran[2] rocks.

TYPE SECTIONS

Because the Permian as an independent sequence was distinguished by the writer (1954)

[1] Consultant, Shell Oil Company, of Canada, Limited.

[2] The history of the term Tunnel Mountain will be more fully presented by P. F. Moore in one of the papers in the forthcoming Carboniferous-Jurassic symposium volume of the American Association and the Alberta Society of Petroleum Geologists.

initially in Highwood Pass, and because a much more complete section exists there than in the Banff type area, it seems expedient to discuss this section before the original type section. The writer, moreover, advances the suggestion that the section at the head of Storm Creek in Highwood Pass be regarded as an alternative or supplemental type section. The exposure is readily accessible where measured in the south wall of the cirque on the east side of the pass, at the source of Storm Creek. The measured section follows.

TRIASSIC

Spray River Formation

Bed		Thickness (Feet)
0	Sandstone, silty, dirty gray brown, thin-bedded, platy splitting. exposed,	9.0′

PERMIAN

Storm Creek Member

1	Chert, solid bed regolithic in part, with limonite; rusty weathering, rough surfaced.	1.7′
2	Sandstone, dolomitic, fairly thin beds, with stromalitin bands; upper 4′ friable and dirty (pre-Spray River weathering?).	9.5′
3	Quartzite, fine, compact, hard, light grey, lower part brown weathering.	5.9′
4	Sandstone, quartzitic, fine, buff to grey, compact, thin bedded, irregularly dolomitic; thin stromatolitic bands, chert in several thin zones.	37.0′
5	Sandstone, white, quartzitic, very fine, well sorted, massive, lower portion light brown, bedded.	160.0′
6	Sandstone, rather poorly sorted, with sub-rounded grains, thin bedded and laminated coarser and finer porous.	4.0′
7	Sandstone, dolomitic, tan, fine, coarser toward middle, top locally white.	63.0′
8	Breccia, fragments: sandstone dolomitic, fine, hard; matrix: buffy to white sandy dolomite.	13.5′
9	Sandstone, dolomitic, quartzitic, very fine, well sorted, light brown, vague "fucoids", local foresetting, upper part porous-weathering. Chert band, grey to white, 12 feet above base.	20.0′
10	Sandstone, quartzitic and dolomitic, dove brown; lower 2 feet poorly sorted into coarser and finer laminae with rounded grains and granules of quartz and chert, top 4 feet better sorted, laminated, locally porous, upper few inches vitrified, white.	8.0′
11	Sandstone, grey, dove weathering, fine, well sorted, very thick bedded, long, steep, plane foresets, top 16 feet massive, craggy, darker brown, quartzitic.	180.0′
	Total: Storm Creek Member	503′

Norquay Member

12	Siltstone, dark grey, argillaceous, micaceous, slabby to shaly, makes deep crevice.	1.5′
13	Sandstone, very dolomitic, buff, fine to very fine, black phosphatic pebbles present 2 to 3 feet below top, 5 feet below top is band of greyish white, fossiliferous chert, another chert band, light grey, vitreous, 40 feet below top, 41 to 46 feet below top rock is honeycombed by casts of ramose bryozoa, remaining 42 feet is dolomitic, calcarenitic sandstone interbedded with dolomitic, quartzitic, very fine sandstone in beds 1 to 4 feet thick, a few chert stringers 30 to 42 feet above base. Fauna: (from chert band 5 feet below top)[1] *Stenopara* aff. S. *gracilis* (Dana), S. *nigris* Crockford. *Stenopara* aff. S. *tasmaniensis* Lonsdale.	85.5′
14	Siltstone, dolomitic, quartzitic, buff, grey green, pink, in firm laminated layers splitting under weather; on shale, maroon, subfissile, on quartzite, greenish; on 1.5 feet of chert, purplish, massive.	7.5′
15	Sandstone, dolomitic, buff, with interbands of pink and grey chert.	7.0′
16	Siltstone, argillaceous, dolomitic, green to pale grey.	2.3′
17	Siltstone, dolomitic, mottled red and green, lower 1.4 feet with lenticular bands of red jasper, red to light brown weathering.	4.7′
18	Siltstone, firm, with red stained druse.	2.6′
19	Siltstone, dolomitic, quartzitic, with interbedded novaculitic chert and scattered red or white druse.	6.0′
20	Porcellanite, dolomitic, grey, pale weathering, appears massive on fresh fracture but weathering reveals very fine lamination due to relief weathering of silty laminae, minor cross lamination. Twelve feet below top is zone of fossiliferous buff dolomite. Band of black chert nodules near base. A few inches higher is band with poorly sorted, rounded sand grains, dark chert granules and pebbles, and debris of silicified fossils, probably derived from underlying bed. Fauna: *Euphemites carbonarius arenarius* Shimer *Dentalium (Plagioglypta) canna* White	75.0′
	Total: Norquay Member	192′
	Total: Rocky Mountain Formation	695′

[1] Madeleine A. Fritz, personal communication.

MISSISSIPPIAN

Tunnel Mountain Formation
Member No. 1

Bed		Thickness (Feet)
21	Dolomite, dark grey, cryptocrystalline, with sandy to argillaceous laminae and sand filled borings, rather thick to thin bedded, much chert near top and base, latter grey, encrinal, white specked, brown weathering. Band 4 to 5 feet above base has abundant brachiopod casts and molds.	17.5′
	Fauna: *Spirifer leidyi* Norwood & Pratten *Cleiothyridina sublamallosa* (Hall) *Dictyoclostus inflatus* (McChesney)	
22	Dolomite, grey, thin bedded, with fine sand stringers and borings, zones of geode-like vugs lined with drusy quartz.	13.5′
23	Dolomite, black, thick bedded, cryptocrystalline, lowest (3′) bed 50% bioclastic, with large masses of black chert ,and large heads of *Syringopora* silicified in top and base.	75.0′
	Fauna: *Syrinogopora pennsylvanica* Shimer *Echinocrinus* sp. A. Crinoid joints *Spirifer leidyi* Norwood & Pratten	
24	Limestone, dolomitic, licorice grey, finely crystalline, dull, argillaceous, silty and fine sandy stringers weather out along some zones, drusy vugs. Fossils silicified weathering out.	39.0′
	Fauna: crinoid joints *Orbiculoidea* sp. A. *Spirifer* sp. (poor) *Cleiothyridina sublamellosa* (Hall) *Composita* sp. A.	

STORM CREEK FORMATION

Bed No. 1 of the above section appears to be a weathering phenomenon of the pre-Spray River erosion surface. The chert is in part a limonite-cemented regolith and the dolomitic sandstone immediately beneath is in places deeply weathered to a virtual soil. Despite these features, the Triassic-Permian contact, like the Permian-Mississippian contact below, appears essentially level in terms of the local outcrop. Regionally, however, such is demonstrably not the case.

The Permian succession at Storm Creek seems to fall naturally into two major divisions, the upper of which, 503 feet thick, is dominantly a quartzitic sandstone, fine grained, well sorted, thickly bedded, clean, and tan to white. Long, steep, smoothly inclined foresets mark the lowest 180 feet. A thin zone of coarser, poorly sorted sandstone with rounded grains lies immediately above the latter, and a second such zone lies 285 feet above the base. The topmost 50 feet is a rather distinctive sub-unit that is more thinly stratified, having interbeds of buffy dolomitic sandstone with small stromatolitic masses and chert.

For this 503-foot upper division of the Rocky Mountain, absent on Tunnel Mountain and Mount Rundle, the writer (1954) proposed the name Storm Creek formation.

NORQUAY FORMATION

The lower division of the Permian sequence, 192 feet thick and comprising beds 12 through 19 of the measured section, is correlated with the Norquay member of Warren (1947) at Banff. It is considerably more varied in lithologic character than the overlying Storm Creek formation, and can be readily subdivided into three members. The uppermost member, 87 feet thick, is principally buff dolomitic sandstone. The 1.5 foot dark micaceous siltstone that marks its top is comparable to the "dirt bands" described by Beales (1950) from the upper part of the Rocky Mountain on Tunnel Mountain, where smooth black chert and phosphate pebbles are also present, as in bed No. 13 of this section.

The chert band that lies 5 feet below the top of the formation at Storm Creek (*vide* bed No. 13) is particularly interesting for its marine fossils. The bryozoa have been studied by Madeleine A. Fritz (personal communication), who concluded that they are Permian in age and closely related to forms occurring in that system in Australia. Molds of what were probably masses of

similar bryozoa perforate a very dolomitic sandstone underlying a second chert band, which appears to be unfossiliferous.

Beneath the buff dolomitic sandstone member lies the 30 foot middle or "red member" of the Norquay formation, embracing beds 14 through 19 of the section. This conspicuous band, a complex of red, magenta, maroon, bright buff, and green siltstone and sandstone, purplish chert, red jasper, and red stained quartz, is readily traced through the Misty Range from Highwood Pass southward. It is less strongly developed to northward on King Creek, on Cougar Creek near Canmore, and on Tunnel Mountain (Beales' 6 foot grey and pinkish buff quartzite (1950, p. 42)).

The basal member, 75 feet thick and constituting bed No. 20, has the appearance of a hard, grey, relatively massive dolomite on fresh surface, but in acid proves to be almost wholly silica and might be termed porcellanite. Weathering etches out alternately finer and coarser laminae. Close to the Mississippian contact included stringers of coarse, poorly sorted, rounded sand grains and black chert granules recall similar clastic zones in the porcellanite at Tunnel Mountain (Beales' 46.25′ bed on page 42, 1950), and along the highway at the foot of Mount Norquay. At these places, angular regolithic chert detritus is included, as it is in a similar stratigraphic position at Lake Minnewanka.

The bellerophont gastropod *E. c. arenarius* and the scaphopod *D. (P.) canna* were recorded previously by Shimer (1926) from the top of the Palaeozoic section at Lake Minnewanka, and ascribed to the Permian. Warren (1947) considers that only about ten feet of his Norquay member, including the fossil bed in question, is present at Lake Minnewanka, between the Triassic above and the Tunnel Mountain below, and in this the writer essentially concurs.

A few miles southeast in the same fault block, at Cougar Canyon near Canmore, the Rocky Mountain remnant is somewhat thicker and includes not only the basal porcellanite member, but the red member, and a limited thickness of still higher, sandy beds. At Eagle Creek, James River gap, (on the other hand) only 50 to 75 feet of the basal part of the Rocky Mountain are present, and the basal conglomerate contains numbers of the Mississippian, (Mount Head) coral *Ekvasophyllum turbineum* Parks. These clearly constituted part of the detritus reworked into the base of the Permian. This interpretation is confirmed by the presence in place in the Rundle, not far below the contact, of beds bearing the Meramecian (Salem) *Spirifer bifurcatus* Hall. This *Spirifer* normally marks a zone in the Mount Head that immediately underlies the zone of *Ekvasophyllum turbineum.* Thus, in the vicinity of James River Gap, the Permian (Rocky Mountain) strata lie on Mississippian beds that in the Misty Range lie about 900 feet below the base of the Permian. Obviously, and despite local appearances of essential conformability, a very substantial regional unconformity exists between Permian and Mississippian strata in Alberta.

In the ranges north of James River gap, the writer has seen the Rocky Mountain beds only along the Athabaska River north of Jasper, where he interprets Brown's (1950) Upper and Middle Greenock as Permian. These rest with the typical porcellanite *cum* coarse clastics upon "Lower Greenock" strata resembling the Mississippian Tunnel Mountain beds farther south.

As in the south, in the more northern localities there seems to be a relationship of heavily bedded cherts below and fine to medium grained quartzites above, homotaxial respectively with the Norquay and Storm Creek formations, but not necessarily time correlative. A case in point is the Windy Point section, submitted by Fox. There, west of Nordegg and about 3 miles northeast of Cline River, he recorded the following section:

30 feet	Sandstone, grey, medium grained, dense, quartzitic, massive, heavily shot with chert, weathering grey.
110 feet	Sandstone, as above, almost completely silicified, with large irregular masses of and some bedded chert.

South from Bow and Kananaskis valleys, we find in the Mount Head area at the top of the Palaeozoic 45 feet of arenaceous, granular dolomite, sandstone, and massive chert, which Douglas (1950) discriminated as the "Upper Part" of his Rocky Mountain formation (using this term in Warren's original (1927) sense). These upper beds he correlated with the Norquay member, a correlation with which the writer concurs. The remainder of his "Rocky Mountain" he

named the Etherington member, and correlated with the Tunnel Mountain member of Banff. This correlation is substantiated by the presence of late Mississippian faunas (Harker, personal communication).

From Plateau Mountain, specimens similar lithologically to Douglas "Upper Part" of the Rocky Mountain and containing the typical lower *Norquay fossils P. canna* and *E. c. arenarius*, were submitted to the writer by J. C. Scott and C. O. Hage, who report a thickness there commensurate with the upper beds at Mount Head.

The most southerly occurrence of the Norquay Member known to the writer is in the Fernie-Flathead area, identified on the basis of collections obtained there by Pirrit for Shell Oil Company. Warren (1928) reported 1,000 feet of limestone, dolomite, quartzite, and chert at the top of the Palaeozoic in the Crowsnest Pass, which presumably are correlative with the Rocky Mountain.

REGIONAL RELATIONSHIP

Considered regionally, there seems to be a progressive eastward truncation of the Rocky Mountain group as a result of pre-Spray River erosion. For example, in the Highwood-Kananaskis area the westernmost fault block examined (at King Creek) showed 826 feet of Rocky Mountain, the next easterly (at Storm Creek) contained 695 feet, whereas the easternmost range (Mount Head) preserved only a 45 foot remnant and the formation is absent in the subsurface of the foothills (Turner Valley). A similar picture obtains in Bow Valley.

Post-Mississippian, pre-Permian erosion likewise truncated the Rundle Group in a direction showing a strong easterly component. This is made evident by comparison of the Misty Range (Storm Creek) section, with 602 feet of Tunnel Mountain beds, with the Front Range (Mount Head) section, containing only 290 feet of Tunnel Mountain ("Etherington"). That the strike of the plane of truncation does not entirely parallel the strike of the mountain structures is indicated, however, by the very deep pre-Permian erosion in the front ranges of more northern areas, as for example in the vicinity of James River gap, discussed above.

ROCKY MOUNTAIN FAUNAS

Shimer (1926) was the first to ascribe a Permian age to the strata at the top of the Palaeozoic section in Alberta, on the basis of "such Permian species as *Euphemus carbonarius* var., *Plagioglypta canna*, and *Bakewellia parva*". Although Warren (1927) does not "altogether concur" in this conclusion, he does cite Lambe's (1916) identification of fish remains with those previously reported from the Permian Park City formation. Several subsequent writers have indicated a correlation with the Permian (Phosphoria formation) of Idaho, Wyoming, and Utah. These correlations (particularly when the supposed Pennsylvanian elements mistakenly identified from the Mississippian part of the original "Rocky Mountain formation" are excluded) are based on very meagre evidence. The independent identification by Dr. Fritz of the bryozoa as also Permian is therefore a welcome addition to the faunal picture.

Finally, the collecting by Pirrit in the course of field studies for Shell Oil Co., of richly fossiliferous Rocky Mountain chert from the Fernie-Flathead area in the Eastern Rocky Mountains of British Columbia, has gone far to substantiate the earlier conclusions. A few small blocks of this chert, secured by Pirrit and studied by the writer, yielded 19 species of organisms, of which seven were specifically identified or closely compared and eight others were given some degree of generic assignment.

Of five pelecypods specifically designated, namely *Schizodus texanus* Clifton, *S. oklahomensis* Beede, *Allorisma* cf. *rothi* (Newell), *Pleurophorus* cf. *albequus* Beede, and *Dozierella gouldi* (Beede), all have been recorded previously from the Middle Permian (Leonardan)

Blaine and Dog Creek formations of Oklahoma and Texas, and four of them from the immediately younger Whitehorse formation there as well. Among the above pelecypods, *Dozierella* as a genus is limited to the mid-Permian.

The association of the pelecypods with numerous *Euphemites* cf. *carbonarus* and *Plagioglypta* (too fragmentary for specific identification) seems to tie the fauna to that identified by Shimer from Lake Minnewanka, and by the writer from Highwood Pass and Plateau Mountain. One discordant note in this seeming faunal harmony is contributed by the single trilobite species in the fauna, a *Ditomopyge* close to *D. decurtata,* which occurs in the higher beds of the Lower Permian, (Wolfcampian) in Kansas. Although the genus ranges down into the Pennsylvanian, it has not previously been recorded as late as the Middle Permian.

Despite the trilobite, however, sufficient evidence now seems at hand to conclude that the Norquay formation is correlative with Middle Permian strata that are widespread in the Cordilleran and Mid-continent regions of the United States.

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THE BELLY RIVER FORMATION

G. K. WILLIAMS[1]

ABSTRACT

The history of nomenclature and a generalized summary of the Belly River formation and its equivalents in Alberta is presented. The location of a few easily accessible sections worthy of examination are noted.

INTRODUCTION

The Belly River formation and its equivalents are of widespread occurrence in central and southern Alberta These sediments comprise a lower wedge of continental beds several thousands of feet thick in the west, thinning to a few hundreds of feet in the east, where their stratigraphic equivalents are marine shales. The upper part of the Belly River is in contact in most of Alberta with a tongue of marine shale, the Bearpaw formation. In western Alberta, including the foothills from the Bow Valley north, the marine Bearpaw is not present and the separation from the overlying beds is difficult or impossible on lithologic evidence. The lower part of the Belly River is in contact in the foothills with the Wapiabi (also known as the Benton or Alberta) marine shales. Farther east, as the more coarsely clastic continental wedge becomes thinner and is replaced by marine strata, it is underlain by the Pakowki shale formation, and still farther east by the Lea Park marine formation.

HISTORY OF NOMENCLATURE

G. M. Dawson (1882) first used the name Belly River formation for a series of continental beds first studied by him on the Milk River, immediately north of the 49th Parallel. Dawson recognized two subdivisions of the formation and referred to them as the upper "Pale and Yellow" beds and the lower "Sombre" beds. The Belly River, as defined by Dawson, conformably overlay the "Lower Dark Shales", which he incorrectly believed to be the upper part of the Colorado shales, and was overlain by the Pierre shale.

D. B. Dowling (1915) subsequently recognized that the "Lower Dark Shales" in Pakowki Coulee were younger than Colorado in age, and he introduced the name Pakowki formation for these shales. He also introduced the name Milk River formation for the sandstone outcropping below the Pakowki beds, which Dawson has considered to overlie the "Lower Dark Shales", thus being in the lower or "Sombre" beds of his Belly River formation. Other names introduced by Dowling were the Foremost formation for Dawson's "Sombre" beds, and the Bearpaw formation for the marine shale overlying the "Pale and Yellow" beds. The name Belly River was retained by Dowling to denote the series including the "Pale and Yellow" beds, Foremost, Pakowki and Milk River formations.

Williams and Dyer (1930) shortened the term "Pale and Yellow" to the "Pale" beds, and restricted the Belly River formation to include only the Foremost and "Pale" beds.

Russell and Landes (1940) introduced the name Oldman for the former "Pale" beds. They considered the Oldman and Foremost as formations and abandoned the term Belly River.

Although officially replaced by the names Oldman and Foremost in the type area in southern Alberta, the term Belly River as a formational unit is still widely used in the subsurface of the plains, as it is often not possible to distinguish from electrical logs, or in outcrop, the boundary between the Foremost and Oldman beds.

Table I illustrates graphically the evolution of the nomenclature in the type area.

[1] Geolgist, J. C. Sproule and Associates, Calgary.

TABLE I

Evolution of Belly River Nomenclature
In The Southern Plains of Alberta

Dawson 1882		Dowling 1915		Williams & Dyer 1930		Russell & Landes[1] 1940
Pierre Shale		Bearpaw Formation		Bearpaw Formation		Bearpaw Formation
Belly River Formation	Pale & Yellow Beds	Belly River Formation	Pale & Yellow Beds	Belly River Formation	Pale Beds	Oldman Formation
	Sombre Beds		Foremost Formation		Foremost Beds	Foremost Formation
Lower Dark Shales			Pakowki Formation		Pakowki Formation	Pakowki Formation
			Milk River Formation		Milk River Formation	Milk River Formation

[1] Russell and Landes proposed that the term "Belly River" be dropped. The name however, has persisted.

DESCRIPTION

The Belly River formation consists of a series of alternating sandstones and shales of fresh, or locally, brackish water deposition. The unit as a whole appears as drab weathering shales and brown to grey, often massive sandstones. Individual beds vary markedly both laterally and vertically. Shales are light to olive green, grey or brown. They are nearly always poorly bedded resulting in a rubbly weathered appearancce. The shales are commonly silty or sandy. Shales alternate with harder layers, ranging in grain size from silt through sandstone to coarse conglomerate. Fine to medium sandstone grains predominate over other grain sizes. Conglomerate layers are generally thin and of limited lateral extent.

In composition the sand particles consist of quartz, chert and feldspar. In the finer phases quartz grains predominate. In the medium phases considerable black chert and argillite grains are found with the quartz. Coarser phases are often richly feldspathic. The cement in the sandstone may be of argillaceous material, iron oxide, kaolin or, rarely, calcite.

Iron oxide is common in the Belly River formation. It occurs in ironstone layers or nodules or, more commonly, as large nodular masses of ferruginous shale or sandstone. The carbonaceous content in the formation is notably variable from one locality to another. Carbonaceous flecks and plant remains are rather common in the sandstones. Thin coal seams of limited areal extent occur throughout the Belly River, but the best seams occur in the transition zone below the Bearpaw shale. Coal is found in that zone in many places in southern Alberta plains and foothills.

Sandstone layers from a few inches thick to about 15 feet (rarely thicker) alternate with shale and silty shale. Sandstones commonly show small scale cross-bedding. The contacts between shale and sandstone layers may be sharp but more commonly they are gradational.

In southern Alberta the Belly River equivalent consists of the Oldman and Foremost formations. Separated on the basis of colour, the uppermost Oldman weathers a lighter colour than the Foremost. In the foothills, however, the Belly River cannot be zoned as the colour distinction is not observed and diagnostic widespread markers are absent.

The contact with the underlying marine shales is transitional and variable from place to place. On Oldfort Creek the gradation is well exposed. The upper part of the Wapiabi transition zone becomes increasingly sandy and grades imperceptibly into massive Belly River sandstones. Hume (1929) noted that south of the Bow River the contact of marine and continental beds varies in such a way that in one locality basal Belly River sandstones are the time equivalent of marine Wapiabi shale in another. Shaw and Harding (1949) show very clearly by their cross-section that this condition exists on a large scale in east-central Alberta. The Belly River formation gains section at the base from east to west, so that the lower section of the formation in the west contains older beds than the base of the formation farther east.

Where the Bearpaw formation is present, the Belly River can be mapped separately from the Edmonton, or its equivalent. The contact with the Bearpaw is gradational but marked, in that the lithology changes from non-marine arenaceous beds to black marine shale. Coal is commonly present in the transition zone. West of the Calgary-Edmonton highway and north of the Bow Valley, the Bearpaw formation is not present, and the Belly River formation is overlain by the lithologically similar Edmonton formation. Where the Bearpaw formation is absent the determination of the top of the Belly River is difficult. Hume (1936) working in the Wildcat Hills, placed the contact at the base of a pebble and cobble conglomerate containing pebbles of porphyry, quartzite and chert. Beach (1942), working north of Hume's area, used a similar conglomerate to mark the base of the Edmonton and noted that it rested on a channelled erosional surface. Farther north in the foothills, the conglomerate has not been found and a Belly River-Edmonton contact cannot be located with assurance. The combined sediments in the Nordegg area are generally referred to as the Brazeau formation, and farther north in the Wapiti River country, as the Wapiti formation.

At the base of the Brazeau and Wapiti formations, a persistent marine sandstone about 50 to 70 feet thick, called respectively the Solomon and Chinook member, is present in the central and northern foothills. This member is generally mapped with the overlying continental series. Because of its marine character, however, it might be included more properly with the Wapiabi formation. As was pointed out above, the base of the Belly River transgresses time boundaries from east to west. It is probable that the same condition exists from south to north, so the placing of the Solomon or Chinook member with one formation or another may be based on similarities in character rather than accurate geological dating.

In the Bow Valley the Edmonton formation is present in a narrow band near the edge of the foothills belt. The Belly River formation here is in faulted contact with the Edmonton, so that the nature of the transition between the two cannot be determined. In the remainder of the valley the Belly River is the youngest Mesozoic formation present and is everywhere subject to post-Laramide erosion.

At the western boundary of the foothills the Belly River formation has been overridden by Palaeozoic rocks (Cambrian in the Bow Valley) along the McConnell thrust fault. Approximately 1,200 feet of Belly River are present beneath Mt. Yamnuska. So far as the writer is aware, the Belly River is the youngest formation overridden by the first ranges of the Rockies anywhere in Albreta.

DISTRIBUTION

Rocks of the Belly River formation, or of equivalent formations are present at the surface or in the subsurface over nearly all of southern and central Alberta. No one section can be considered the type locality. The name originated from good outcrops on the Belly River south and west of Lethbridge (Dawson 1882). Excellent exposures of the Foremost beds, showing both contacts, are present in the Milk River gorge north for 15 miles from the 49th Parallel. Dowling's (1915) type area for his subdivision of the Belly River was in Chin Coulee, near the town of Foremost. Good exposures of the Oldman beds can be seen in the valleys on the west flank of the Cypress Hills near the town of Manyberries. The type locality of the Oldman is along the Oldman River at and west of Lethbridge, where it is overlain by Bearpaw shale.

In the southern foothills region the most complete exposure of the Belly River can be seen on the Highwood River in Sections 19 and 20, Township 18, Range 2, W.5th (Hume 1929). Farther north nearly complete exposures can be seen along the James River west of Sundre (Beach 1942). Good exposures of the Brazeau formation, the lower part of which is equivalent to the Belly River, are not common, and none are readily accessible from highways. The Wapiti formation is likewise inconveniently located. However, fair sections of the latter can be observed along the banks of the Wapiti River near the Wembley ferry, southwest of Grande Prairie.

TABLE II

Correlation Chart

<table>
<tr><th>Southern Plains</th><th>Southern Foothills</th><th>South-Central Foothills</th><th colspan="2">North-Central Foothills</th><th colspan="2">Northern Foothills</th><th>Central Plains</th></tr>
<tr><td>Blood Reserve</td><td>St. Mary River</td><td>Edmonton</td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td>Edmonton</td></tr>
<tr><td>Bearpaw</td><td>Bearpaw</td><td colspan="2" rowspan="2">Bearpaw</td></tr>
<tr><td>Oldman</td><td rowspan="2">Belly River</td><td rowspan="2">Belly River</td><td colspan="2" rowspan="2">Brazeau</td><td colspan="2" rowspan="2">Wapiti</td><td rowspan="2">Belly River</td></tr>
<tr><td>Foremost</td><td rowspan="3">Lea Park</td></tr>
<tr><td>Pakowki</td><td rowspan="3">Wapiabi</td><td rowspan="3">Wapiabi</td><td rowspan="3">Wapiabi</td><td></td><td rowspan="3">Wapiabi</td><td></td></tr>
<tr><td>Milk River</td><td>Solomon Sandstone</td><td>Chinook Sandstone</td></tr>
<tr><td>Upper Colorado</td><td></td><td></td><td>Upper Colorado</td></tr>
</table>

In the Bow Valley, although no continuous sections are present, many readily accessible outcrops are present along the Bow River near the Banff highway. The lower contact, with the Wapiabi formation, can be seen on Oldfort Creek about one mile upstream from the highway, and also on the east bank of Jumpingpound Creek near the Sulphur Plant, and at numerous other localities.

CORRELATION

A correlation chart, Table II, is included, showing the regional correlation of the Belly River with other formations in Alberta. The time transitional nature of the lower contact has been discussed separately, indicating that the base of the formation is not everywhere the same age. Progressively older beds are present in the Belly River from east to west.

Correlation with other formations is generally based on stratigraphic position, although Dinosaur bones and a few brackish water fossils have proven helpful. For details of characteristic palaeontology, the reader is referred to the original works listed in the bibliography.

ECONOMIC GEOLOGY

Coal has been mined from the Belly River or its equivalents since the early days of Alberta's history. Generally speaking, the most important Belly River coal reserves are located in southern Alberta. In this respect, the Belly River-Edmonton formations resemble the Kootenay-Blairmore formations, in that conditions favoring widespread coal deposits shifted from south to north during geological time. The largest and best known coal operations from the Belly River strata are in the vicinity of Lethbridge.

The widespread occurrence of natural gas in the Belly River formation has been known for many years. It has been especially troublesome in causing blowouts from shallow structure-test holes drilled on the Plains. There are several potential commercial gas wells in the Belly River formation.

Although there are probably sizable reserves of gas and oil in the Belly River formation, it is not likely to become an important objective in wildcat drilling, owing to the unpredictable and lenticular nature of its individual sandstone horizons.

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THE JUMPINGPOUND GAS FIELD[1]

R. MARTIN[2]

INTRODUCTION

The Jumpingpound Gas Field is situated in the Foothills Belt of the Rocky Mountains, near its eastern edge, some distance north of the Turner Valley oil field and about 22 miles west of Calgary (see Figure 1).

The field area is some 12 miles long and it extends in a south-southeasterly direction from Section 21, Township 26, Range 5 to Section 29, Township 24, Range 4, West of the Fifth Meridian (see Figure 5). The two northernmost wells, Units 13 and 14, lie north of the Bow River and on either side of the Calgary-Banff highway. The width of the field varies from approximately one half to two miles; it consists of only one row of producing wells spaced approximately one mile apart. Of the fourteen wells drilled by Shell Oil Company of Canada, Limited, since 1945, eleven are flowing gas wells, two are marginal gas wells abandoned as non-commercial (Units 3 and 8), and one (Unit 2) is dry and abandoned.

The surface geology of the area was mapped by G. S. Hume, Geological Survey of Canada, and was published by the Department of Mines and Resources (1941). The surface structure consists of numerous NNW-SSE trending imbricate Upper Cretaceous thrust blocks, bounded on the east by the Jumpingpound thrust fault, which in this area forms the approximate eastern boundary of the Foothills Belt. A short distance to the west of the outcrop of the Jumpingpound thrust fault, the Upper Cretaceous forms an asymmetrical front fold which was the objective of much early drilling.

Below the Jumpingpound thrust fault, structural conditions are very different. The producing formation, the porous dolomite of the Turner Valley formation of the Mississippian Rundle Group (mostly referred to as the Rundle), is affected by thrust faulting too, but to a considerably lesser extend than the overlying Cretaceous. Overlying a sole fault, at least two thrust blocks have been recognized within the gas producing area; the underthrust Mississippian and Devonian below the sole fault are water bearing.

TOPOGRAPHY

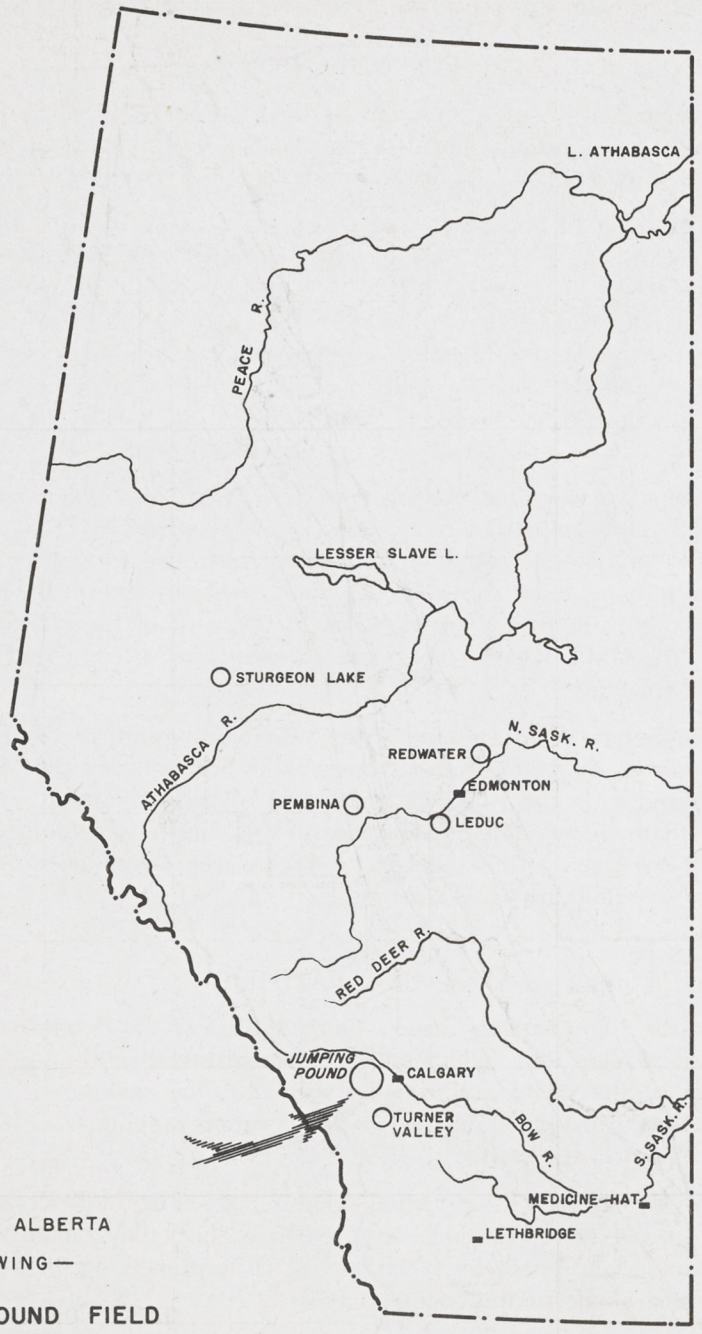
The scenery of the Jumpingpound area is fairly typical of the Foothills Belt, being marked by a series of parallel ridges and valleys with a northnorthwest-southsoutheast trend, conforming with the strike of the strata and roughly parallel to the mountain front to the west. The maximum relief is approximately 1,700 feet, with elevation ranging from 4,000 feet above sea level in the east to 5,700 in the west.

Differential erosion has been the principal agent in fashioning the landscape, the ridges being invariably formed of the more resistant rocks, whereas the valleys, many of which are filled with muskeg, are underlain by shales. Terraces of river gravels occur along the Bow River and to a lesser extent along Jumpingpound Creek.

The area is drained by the Bow River and its tributary, Jumpingpound Creek. Their courses as well as that of Little Jumpingpound Creek, a tributary to Jumpingpound Creek,

[1] Published by permission of Shell Oil Company of Canada, Limited.

[2] Area Production Geologist, Shell Oil Company, Calgary. The writer is indebted to Messrs. W. D. Bell, C. W. Daniel, E. K. Schluntz and M. D. Winning for their contributions to this paper concerning the geology, drilling and completion methods, reservoir engineering, and gas plant operations, respectively, and to Messrs. L. A. Lewis, N. W. Martison, P. F. Moore, F. H. van Goor, A. G. T. Weaver and B. Van der Schilden and many others for their valuable comments and criticisms of the manuscript.



MAP OF ALBERTA
—SHOWING—
JUMPING POUND FIELD

FIGURE 1

TYPE LOG JUMPING POUND FIELD

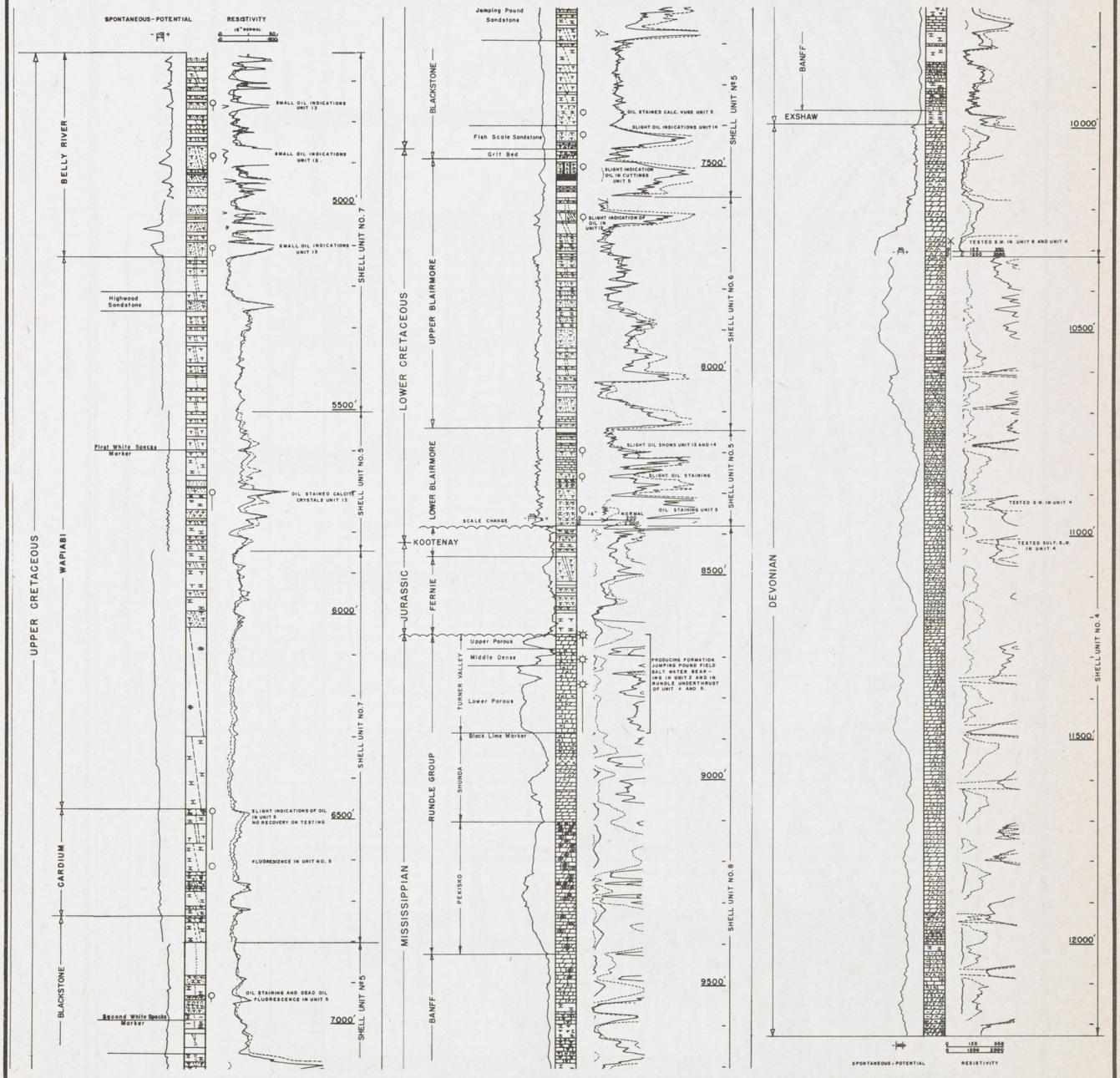
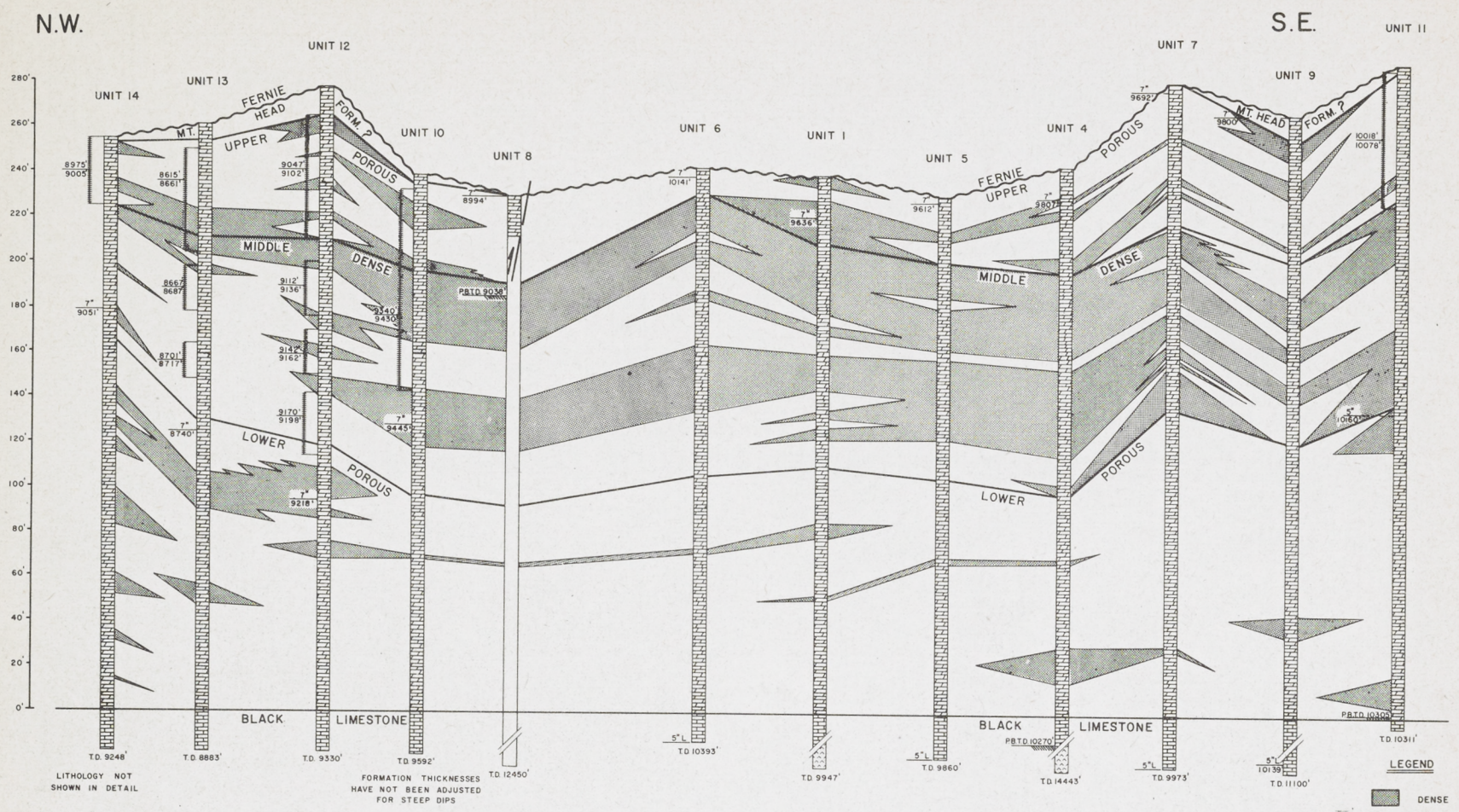


FIGURE 2



PENETRATION CHART

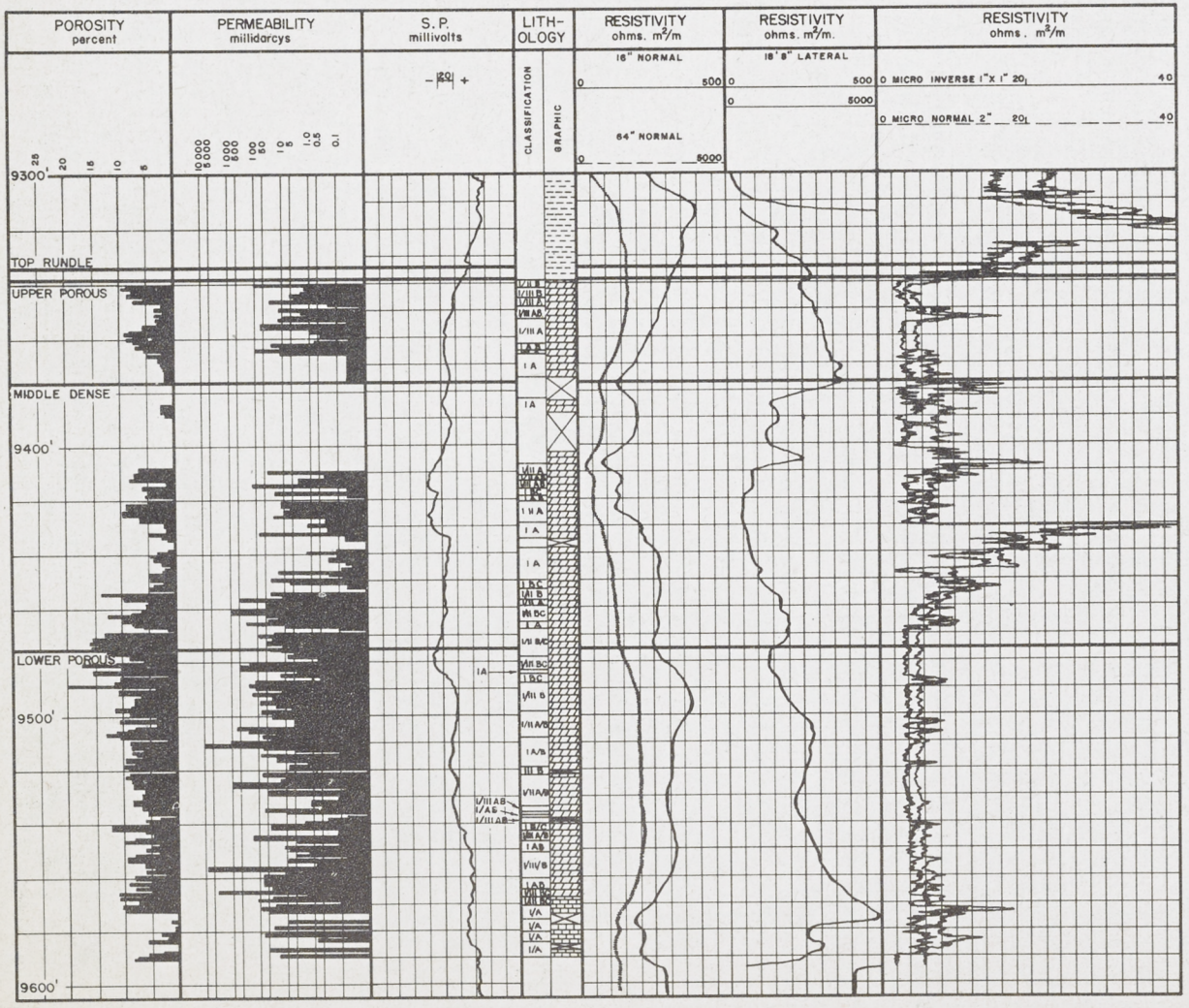
SHOWING

DEVELOPMENT OF POROUS AND DENSE ZONES IN TURNER VALLEY FORMATION - JUMPING POUND FIELD

HORIZONTAL SCALE

2000' 0 2000' 4000' 6000'

FIGURE 3



LEGEND		
GRAPHIC		CLASS'N OF CARBONATES
DOLOMITE		I – COMPACT CRYSTALINE
LIMESTONE		II – CHALKY
		III – GRANULAR
SHALE		A – PORES < 0.01 mm.
NO SAMPLES		B – PORES 0.01 – 0.10 mm.
		C – PORES 0.10 – 2.0 mm.

LOGGING DATA			
MUD			
WT.	9.6	LBS/GAL.	
RES.	3.6	OHM-M AT	60 °F.
WATER LOSS	4.4	CC./ 30 MIN.	
BORE HOLE			
SIZE	8-5/8	INCHES	
TEMP.	164	°F. AT	9592 FT.

PETROPHYSICAL DATA
— ON —
TURNER VALLEY FORMATION

JUMPING POUND UNIT NO. 10

LSD. 11, SEC. 3, TWP. 26, RGE. 5, W. 5 MER.

FIGURE 4

cut across the regional strike, whereas the smaller tributaries mostly occupy the valleys between the various ridges.

The rugged terrain, locally thick gravel deposits, and the abundant wooded areas present many obstacles to seismic surveying.

HISTORY OF DEVELOPMENT

Drilling in the Jumpingpound area began in 1914 with Purity Oil Company's No. 1 well, in the northern part of the present field, which reached a depth of only 1,255 feet. The Northwest Company and others drilled four wells in the southern part of the area during the period 1914 to 1921. At the end of 1939 a total of nine wells had been drilled with the objective of testing the Upper Cretaceous of the front fold and the other imbricate fault blocks overlying the Jumpingpound thrust fault, the deepest of which was Brown Consolidated Rabson No. 1 (6,885 feet). All these wells were abandoned.

Following the publication of a cross-section by Hume (1940) which indicated the possibility of finding favourable structural conditions in the Mississippian, below the Jumpingpound thrust fault, a seismic survey of the area was undertaken by Shell Oil Company of Canada, Limited. Some seismic work had been done previously for Rabson Oil Company, Limited and its associates, who at that time largely controlled the acreage. In 1942 Shell acquired the petroleum and natural gas rights held by Rabson.

On the basis of the seismic results, the discovery well No. 4-24-J (later renamed Unit 1) was drilled in 1944 and successfully completed as a gas-condensate well in the Rundle, the top of which was encountered at 9,618 feet (5,598 feet below sea level). This was followed by the drilling of Units 2 and 3 along a dip section extending southwest from the discovery well. Unit 2 found the Rundle too far downdip and below the water table, and Unit 3 subsequently established the gas-water contact at 6,436 feet subsea. Unit 4, drilled to the southeast and on strike with Unit 1, was drilled through the sole fault into the underthrust Mississippian and Devonian, both of which were found to be waterbearing.

Meanwhile, the field was unitized in 1945 under the terms of the Jumpingpound Unit Agreement, made between the Crown and Shell Oil Company of Canada, Limited and joined by almost all of the freehold lessors and royalty owners in the area. The unit area is some 16 miles in length and varies from 1½ to 2¾ miles in width; its total area is 18,833 acres.

After the completion of Unit 4 in 1947, development ceased until a market for the gas became available in 1950. Thereafter one mile stepouts were drilled to the northwest and southeast of Unit 1 along the approximate crest of the structure, Unit 14 being the last well completed to date. One of these wells, Unit 8, which encountered only 19 feet of Rundle carbonate above the sole fault, was drilled to the underthrust Mississippian and Devonian, however with equally disappointing results as Unit 4. The remaining wells were all bottomed in the "Black Lime" underlying the Turner Valley formation.

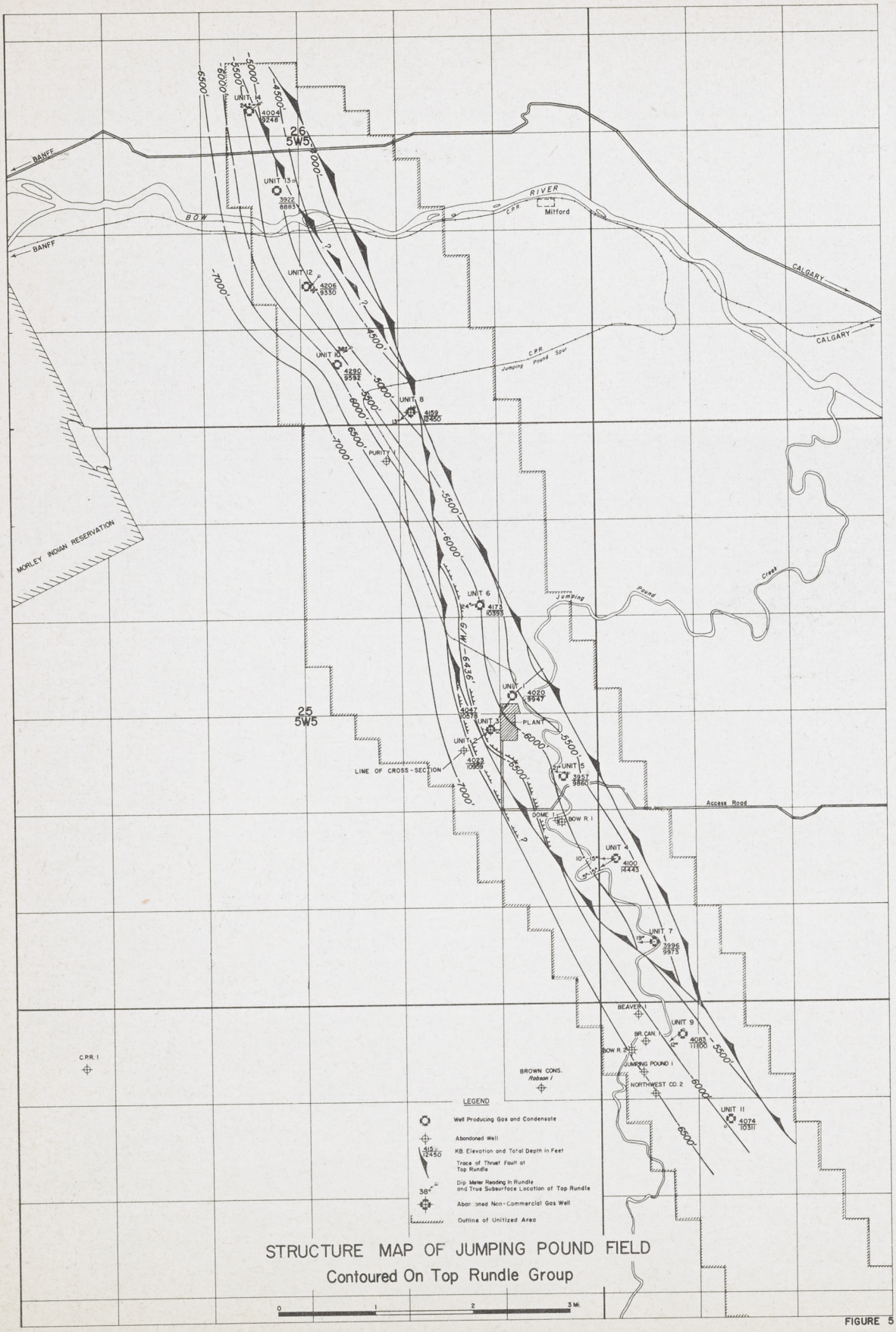
Construction of the gas plant began in 1950 and the plant went on stream in May 1951, and with the subsequent gradual increase in demand the processing facilities, have been expanded twice.

STRATIGRAPHY

The Cretaceous formations of the Jumpingpound area are well known from the surface exposures, as mapped by G. S. Hume (Department of Mines and Resources, 1941). In addition, these and the deeper formations down to the Devonian were penetrated in various wells drilled in the area, some of which were sampled with great care, and the cuttings examined in conjunction with the electric logs. The repetition of strata by thrusting and the distortion

of their true thicknesses by steep dips present a considerable handicap to attempts to establish the normal sequence. Figure 2 is a composite type log built up from section believed to be undisturbed in the indicated wells and corrected for dip. The stratigraphic succession thus established is given below; due to the structural factors already mentioned, the thicknesses given are only approximate.

Age	Formation	Lithology	Thickness
Upper Cretaceous	Edmonton	Sandstones, shales, and coal beds.	Unknown
	Belly River	Sandstones, shales, conglomerates, and coal.	More than 1,200 feet
	Wapiabi (formerly Upper Alberta)	Shales and shaly sandstones. Includes the Highwood Sandstone and the First White Specks marker.	1,350 feet
	Cardium	Sandy shales. Includes the Cardium sandstone.	250 feet
	Blackstone (formerly Lower Alberta)	Shales and sandy shales. Includes the Jumpingpound sandstone and the "Fish Scale" sandstone. Grit bed at the base.	750 feet
Lower Cretaceous	Upper Blairmore	Non-marine sandstones and shales.	650 feet
	Lower Blairmore	Limestones, shales, and siltstones, possibly lacustrine in part, with the Dalhousie Sandstone at the base.	250 feet
		Unconformity.	
	Kootenay	Non-marine sediments, comprising coals, coaly shales, and siltstones.	100 feet
Jurassic	Fernie	"Brown Sandstone" – represents a transition from non-marine to marine sediments. Marine shales, containing a Belemnite zone and glauconite towards the base.	200 feet
		Unconformity.	
Mississippian Rundle Group (formerly Madison)	Mount Head	Absent in most wells as a result of erosion.	Up to 13 feet
	Turner Valley	Gas producing dolomite, subdivided into:	
		Upper Porous – contains a number of streaks of varying porosity, not concentrated in one main horizon as in Turner Valley,	Average 43 feet
		Middle Dense – represents the dense zone between the two producing zones of Turner Valley,	Average 64 feet
		Lower Porous – equivalent to the Lower Porous Zone of Turner Valley.	Average 136 feet
	Shunda	Dark Limestone ("Black Lime marker") at the top, followed by anhydrite and dolomite.	230 feet
	Pekisko	Limestone.	300 feet
	Banff	Shales.	500-600 feet
	Exshaw	Carbonaceous shale.	30 feet
Devonian	Upper and Middle Devonian	Anhydritic dolomite.	2,000 feet penetrated in Unit 4



STRUCTURE MAP OF JUMPING POUND FIELD

Contoured On Top Rundle Group

FIGURE 5

Douglas (1953), in a preliminary note on the Carboniferous stratigraphy of the southern foothills, suggested that the productive zones of the Jumpingpound field do not occur in the same interval as those of the Turner Valley field, but are developed in the Mount Head formation. In our opinion, however, the productive beds in the Jumpingpound field correlate with the Turner Valley formation.

The Turner Valley formation consists of buff coloured calcareous dolomite with partings of gray and green pyritic shale. Pyrite and anhydrite inclusions occur in the dolomite. Horizontal and vertical fractures are present, and the porosity is provided by small vugs and by intercrystalline pores. The unconformable top of the Rundle Group, as met in the wells, lies either within the Upper Porous Zone of the Turner Valley formation or is separated from the top of this formation by a few feet of tight dolomite or dolomitic limestone, which is believed to be part of the Mount Head formation.

The gas accumulation is found principally in the Upper and Lower Porous Zones. Varying thicknesses of pay occur also in the intervening Middle Dense Zone (see Figure 3). This latter zone is characterized by a higher proportion of shale than the other two, although in some wells in the northern part of the field the total pay in the Middle Dense is approximately equal to that in either of the other two. The total net pay as estimated from cores and logs ranges from 95 to 165 feet in the individual wells, with an average of 140 feet. Figure 4 illustrates the details of the pay zone for well Unit 10. Its characteristics as determined from core data provided by the same well are given below:

	Net Pay (Feet)	Average Porosity %	Average Permeability (md.)	Porosity x feet	Permeability x feet (md. ft.)
Upper Porous	17.2	6.4	28	1.10	474
Middle Dense	21.6	7.1	9	1.54	192
Lower Porous	106.2	9.1	55	9.65	5,880
Total	145.0	8.5	45	12.29	6,546

The average porosity of the net pay for the whole field is 8.2 per cent. The true overall reservoir permeability, as derived from bottom hole pressure build-up data, averages about 4 millidarcys rather than the 45 millidarcys indicated by the above core data for well Unit 10. An average connate water saturation of 10 per cent has been calculated from core analyses and electric logs.

STRUCTURE

The surface geological features of the Jumpingpound area are quite similar to those of Turner Valley, which adjoins it to the south. A great number of parallel NNW-SSE striking thrust faults separate the Upper Cretaceous sequence into steeply westward dipping thrust blocks, many of which have a core of erosion-resistant Cardium sandstone. The eastern limit of this imbricate zone, and approximately of the Foothills Belt in general, is formed by a major westward dipping fault, the Jumpingpound thrust fault, which runs more or less parallel to but about six miles to the east of the Turner Valley surface anticline. A short distance to the west of the outcrop of the Jumpingpound thrust fault, the beds of the Upper Cretaceous form an asymmetrical front fold, which is broken up by subsidiary thrust faults. This anticline, which is thus a northeast offset to the Turner Valley anticline, although bearing a superficial resemblance to the latter, is in effect quite different at depth, in that it involves only Cretaceous beds above the Jumpingpound thrust fault. In some of the older wells on the west flank the fault plane coincides with the top of the Jurassic Fernie formation.

Below this fault, the cross-section (Figure 6) shows four more steeply westward dipping thrust blocks involving Cretaceous beds, separated by faults steeper than and apparently overridden by the Jumpingpound thrust fault. The Cretaceous beds involved in these fault blocks vary in dip from 10 degrees to 64 degrees.

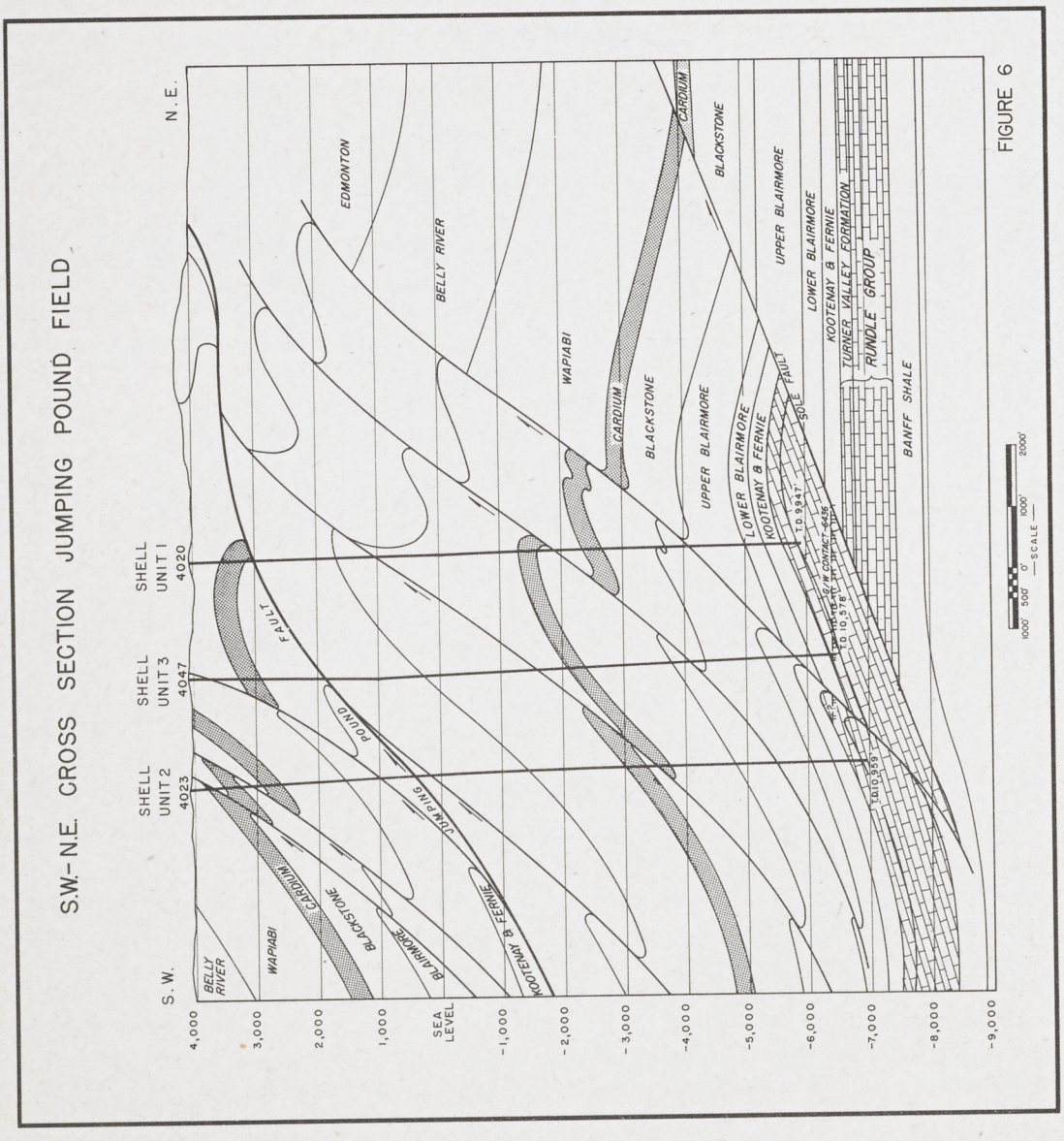

S.W.-N.E. CROSS SECTION JUMPING POUND FIELD
S. W.
N. E.
SHELL UNIT 2 4023
SHELL UNIT 3 4047
SHELL UNIT 1 4020
BELLY RIVER
WAPIABI
MINNEHIK CARBONDALE
BLACKSTONE
BLAIRMORE
KOOTENAY & FERNIE
TUNA PING
POUND
FAULT
EDMONTON
BELLY RIVER
WAPIABI
CARDIUM
BLACKSTONE
UPPER BLAIRMORE
LOWER BLAIRMORE
KOOTENAY & FERNIE
SOLE FAULT
UPPER BLAIRMORE
LOWER BLAIRMORE
KOOTENAY & FERNIE
TURNER VALLEY FORMATION
RUNDLE GROUP
BANFF SHALE
CARDIUM
BLACKSTONE
TD 9947'
TD 10,159'
TD 10,359'
O.W.C. CONTACT -6436
SEA LEVEL
4,000
3,000
2,000
1,000
-1,000
-2,000
-3,000
-4,000
-5,000
-6,000
-7,000
-8,000
-9,000
1000' 500' 0 SCALE 1000' 2000'

FIGURE 6

SUMMARY OF PRODUCTION AND SALES

JUMPING POUND FIELD

Shell Oil Company of Canada, Limited

YEAR		RAW GAS METERED AT WELLS (MMCF)												TOTAL (MMCF) METERED AT WELLS	CONDENSATE PRODUCTION BBL.	SALES OF PLANT PRODUCTS			
		NO. 1	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7	NO. 9	NO. 10	NO. 11	NO. 12	NO. 13	NO. 14			RESIDUE GAS (MMCF)	CONDENSATE BBL.	GASOLINE BBL.	SULPHUR S. TONS
1944		96												96	642				
1945		349												349	3,072				
1946		346	30											376	2,445				
1947		330	-	64										394	2,621				
1948		23	-	52										75	741				
1949		-	-	-										-	-				
1950		53	-	-										53	362				
Cumulative		1,197	30	116										1,343	9,883		11,932		
1951	Jan.	70	-	-										70	574		762		
	Feb.	61	-	131										192	1,687		483		
	Mar.	67	-	-										67	559		665		
	Apr.	126	-	-										126	1,421	76	279		
	May	175	-	136	174									485	4,694	379	2,721	760	
	June	134	-	234	130									498	4,541	397	6,604	1,505	
	July	132	-	270	-									402	3,670	317	2,842	1,122	
	Aug.	175	-	185	87									447	4,258	369	3,287	1,232	
	Sept.	67	-	182	182									431	3,880	347	4,364	1,674	
	Oct.	34	-	278	294									604	4,963	496	3,358	1,140	
	Nov.	188	-	239	211									638	6,002	536	9,423	3,196	
	Dec.	166	-	221	190	199								776	6,992	630	4,214	1,955	
Total	1951	1,395	-	1,874	1,268	199								4,736	43,221	3,547	39,002	12,582	
Cumulative		2,592	30	1,990	1,268	199								6,079	53,104	3,547	50,934	12,582	
1952	Jan.	158	-	208	185	241	45							837	6,859	657	9,024	3,219	
	Feb.	149	-	189	155	199	-							692	6,303	583	6,226	2,222	
	Mar.	146	-	223	175	203	-							747	6,852	637	5,416	1,612	
	Apr.	43	-	227	192	208	-							670	5,943	558	806	200	
	May	-	-	206	198	188	-							592	5,330	497	6,143	1,702	
	June	87	-	123	101	83	-							394	3,605	322	9,607	2,009	453
	July	154	-	6	130	163	5							458	4,689	389	4,405	785	979
	Aug.	82	-	180	111	-	56							429	4,477	362	3,254	1,104	454
	Sept.	-	-	143	108	-	212							463	4,451	388	5,575	1,491	878
	Oct.	108	-	99	148	105	95							555	5,180	455	5,054	1,212	434
	Nov.	191	-	193	97	157	203							841	7,847	690	6,339	1,502	900
	Dec.	56	-	184	184	47	207							678	5,727	518	7,172	1,385	17
Total	1952	1,174	-	1,981	1,784	1,594	823							7,356	67,263	6,056	69,021	18,443	4,115
Cumulative		3,766	30	3,971	3,052	1,793	823							13,435	120,367	9,603	119,955	31,025	4,115
1953	Jan.	209	-	198	216	211	217	-						1,051	9,561	875	8,545	1,829	926
	Feb.	173	-	177	175	176	176	20						897	8,368	719	8,919	1,632	412
	Mar.	223	-	216	207	212	217	-						1,075	10,185	888	8,618	1,874	443
	Apr.	50	-	239	244	237	255	-						1,025	9,779	848	3,827	930	475
	May	-	-	218	221	221	220	-						880	8,282	736	7,950	2,738	-
	June	-	-	156	142	110	188	-						596	5,312	472	7,097	2,332	-
	July	79	-	94	137	161	109	-						580	5,666	494	8,032	2,310	945
	Aug.	232	-	-	100	93	174	-						599	5,526	487	9,413	2,876	925
	Sept.	198	-	-	158	98	192	-						646	6,106	543	5,748	2,654	931
	Oct.	197	-	178	128	162	95	-						760	7,254	662	7,175	3,239	912
	Nov.	167	-	172	193	180	215	107						1,034	9,696	887	9,786	4,268	910
	Dec.	200	-	160	177	186	230	171		20				1,144	10,302	943	10,141	4,234	922
Total	1953	1,728	-	1,808	2,098	2,047	2,288	298		20				10,287	96,037	8,554	95,251	30,916	7,801
Cumulative		5,494	30	5,779	5,150	3,840	3,111	298		20				23,722	216,404	18,157	215,206	61,941	11,916
1954	Jan.	240	-	199	240	232	278	249	-	2	12			1,452	12,443	1,221	10,479	5,217	1,388
	Feb.	126	-	127	174	160	130	185	-	191	-			1,093	9,950	917	11,521	5,047	921
	Mar.	72	-	158	190	196	157	219	-	210	-			1,202	8,140	1,013	6,797	3,878	450
	Apr.	-	-	100	191	191	153	209	-	200	-	72		1,116	(6,511)	884	540	1,128	992
	May	-	-	181	150	58	68	225	-	205	-	-		887	3,512	746	2,246	2,561	-
	June	-	-	116	149	35	-	178	45	158	-	-		681	1,458	581	-	2,376	-
	July	-	-	77	96	22	19	204	-	199	-	-		617	1,386	525	-	2,901	945
	Aug.	-	-	118	53	157	135	140	-	62	-	93		758	(2,323)	555	-	2,935	659
	Sept.	-	-	114	181	206	233	-	69	91	-	-		894	617	719	-	2,255	445
	Oct.	-	-	131	166	186	216	169	15	179	-	-		1,062	1,929	887	-	3,437	1,378
	Nov.	-	-	125	222	219	252	183	54	174	-	-		1,229	3,919	1,039	-	3,168	923
	Dec.	-	-	119	227	180	186	209	180	183	47	-	92	1,423	1,373	1,113	-	2,665	1,190
Total	1954	438	-	1,565	2,039	1,842	1,827	2,170	363	1,854	59	165	92	12,414	35,902	10,160	31,583	37,568	9,291
Cumulative		5,932	30	7,344	7,189	5,682	4,938	2,468	363	1,874	59	165	92	36,136	252,306	28,317	246,789	99,509	21,207
1955	Jan.	-	-	142	184	166	138	160	312	195	308			1,605	4,437	1,360	5,033	3,963	921
	Feb.	-	-	79	164	146	161	154	272	174	273	-	-	1,423	11,424	1,190	11,638	6,388	956
	Mar.	-	-	151	1	152	223	68	298	31	286	-	-	1,210	10,264	1,009	11,062	4,597	-
	Apr.	-	-	27	(68)	162	191	134	284	-	318	-	-	1,048	9,746	879	8,726	3,492	-
	May	-	-	130	(98)	156	66	141	262	-	310	-	-	967	10,535	803	9,437	3,300	866
	June	-	-	146	(103)	134	48	-	249	-	257	-	-	731	7,148	569	8,736	3,521	1,004
	July	-	-	155	(102)	163	17	-	262	-	276	-	-	771	15,077	616	12,727	2,133	3,776
	Aug.	2	-	117	(102)	43	177	224	21	210	47	-	-	739	20,468	602	19,920	2,960	4,253
	Sept.	64	-	129	(95)	161	168	154	77	164	75	-	-	897	20,530	737	20,534	3,806	732
	Oct.	124	-	61	25	169	136	-	257	-	271	168	-	1,211	19,078	1,019	19,850	4,130	359
	Nov.	123	-	96	(80)	168	216	168	290	-	50	423	78	1,532	17,816	1,244	17,688	5,800	681
	Dec.	102	-	48	(83)	158	180	247	310	-	67	365	309	1,703	16,850	1,412	18,698	7,213	[illegible]
Total 1955		415	-	1,281	(357)	1,778	1,721	1,450	2,894	774	2,538	956	387	13,837	184,238	11,440	163,249	51,303	14,430
Adjustments		(34)		(35)	(29)	(16)								(114)	106				
Cumulative		6,313	30	8,590	6,803	7,444	6,659	3,918	3,257	2,648	2,597	1,121	479	49,859	416,650	39,757	410,038	150,812	[illegible]

Deeper still, the Jurassic and Mississippian are found to be affected by a well marked thrust fault, of considerably lesser inclination than the overlying faults, which has been traced by reflection seismic surveys over a considerable distance. This sole fault separates the gas bearing overthrust Rundle from the undisturbed underthrust block, which was penetrated in wells Unit 4 and 8, but found to be waterbearing in both the Mississippian and the Devonian. The top Rundle in this block occurs at around 6,600 feet subsea; its structural attitude is close to horizontal. The sole fault has not been traced in surface outcrops and appears to be absorbed in the shales of the overlying Cretaceous.

The overthrust Rundle has been encountered at depths ranging from 4,832 (Unit 8) to 6,616 feet subsea (Unit 2). It is complicated by subsidiary thrust faulting which may be connected with at least one of the steep faults affecting the overlying Cretaceous. Duplications of section have been registered in various wells from as deep in the stratigraphic sequence as the "Black Lime" to as high as the Upper Blairmore. The simplest picture (Figure 5) connects all of these into one subsidiary fault of sinuous trace which, by cutting below the gas-water contact between wells Unit 2 and 3, effectively divides the Jumpingpound gas field into three separate reservoirs, with an indication of a possible fourth one at the northern end. However, the initial bottom hole pressures measured in the South Block wells, after considerable previous withdrawals from the Central Block were about 190 pounds less than the initial pressure in the remainder of the field, suggesting limited communication between adjoining blocks. Also of interest in this connection is that pressure build-up data from Unit 12 suggest that the subsidiary fault cutting wells Unit 14 and 13 may extend southward past the first well.

DRILLING AND COMPLETION METHODS

The following is a brief summary of the latest drilling and completion methods that have been used by Shell Oil Company of Canada, Limited in the Jumpingpound Rundle gas field.

Well depths, excluding the two holes drilled into the underthrust block, range from 8,863 to 11,100 feet, and average around 9,200 feet. Approximately 3½ months are required to drill and complete an average Jumpingpound gas well.

Approximately 950 feet of 13⅜″ surface casing is cemented in a 17½″ hole. Beginning with well Unit 10, it has been the practice to drill a12¼″ hole from under the surface casing using the "packed hole" drilling technique (11¼″ drill collars in a 12¼″ hole). An oil emulsion lime base drilling mud is used and has been found to be very successful in maintaining the hole in good condition, especially in drilling through the first 7,000 feet of highly disturbed section, which includes several faults and formation dips varying from 10° to 64°.

Intermediate casing strings were required on most wells before the packed hole and lime base mud techniques were adopted, but Unit 14, the last well drilled in the field, was drilled to total depth of 9,428 feet without intermediate casing.

Seven inch production casing is cemented near the base of the Middle Dense Zone, leaving the Lower Porous Zone open. The 7″ casing is then drilled out, the Upper Porous and Middle Dense Zones are perforated, isolated by production packers, selectively acidized, and flow tested through 2½″ tubing. The Lower Porous Zone is then acidized selectively and the three zones are brought into production together.

In the older wells up to and including Unit 9 (see Figure 3), 7″ casing has been cemented at the top of the producing section and completion has been either in open hole (Unit 1 and 4) or with 5″ liner.

The majority of the wells drilled to date have deivated in a northeast to east-northeast direction. Horizontal deviation ranges in the order of a thousand feet east and 600 feet north

of surface location. For details on the way some of the problems posed by crooked holes were solved, the reader is referred to the article by Booth and Angrebrandt (1954).

ACCUMULATION AND PRODUCTION

Although numerous small shows of oil have been reported from the Cretaceous (Figure 2), and several of the shallow wells drilled to test the formations above the Jumpingpound thrust fault reported a number of gas shows (in one case flowing 100,000 cubic feet per day), commercial production is limited to the gas condensate reservoir in the Turner Valley formation of the Mississippian Rundle Group. The same formation produces oil in the Turner Valley field to the south, but in Jumpingpound no oil column has been encountered. The gas-water contact was established at 6,436 feet subsea in well Unit 3.

The eleven producing wells have theoretical open flow potentials of between 8 and 34 million cubic feet of gas per day, averaging 24 MMcf per well, the field total being 267 MMcf per day. The total field deliverability into the present gathering system, operating at 1,000 psi line pressure, is about 160 MMcf per day. A summary of month-by-month production and sales is given in Figure 7. Cumulative production to June 1 1956 amounted to 57½ billion cubic feet of raw gas, and total sales to that date were 46 billion cubic feet of pipeline gas. Lack of a market for the liquid hydrocarbon products, particularly during 1954, led to their underground storage in Well Unit 1, which accounts for the fact that no gas was produced from this well during that period. During 1955 residue gas was injected into well Unit 5 in an effort toward levelling plant operations throughout the year.

The reservoir appears to be of the "closed" or depletion type. The original reservoir pressure was 3,980 p.s.i.g. at 5,850 feet subsea, the original reservoir temperature 194°F.

The crude natural gas is made up of the following constituents (Munn, 1952):

Methane	84.2	mole.	per	cent
Ethane	3.8	"	"	"
Propane	1.0	"	"	"
Butanes	0.5	"	"	"
Pentanes and higher	0.8	"	"	"
Carbon dioxide	6.2	"	"	"
Hydrogen sulphide	3.5	"	"	"

This wet gas yields 9.3 barrels of condensate per million cubic feet, which is removed by separation. The hydrogen sulphide, the carbon dioxide and 3.5 barrels of natural gasoline per MMcf are then removed at the gas plant in order to produce a sweet dry gas of pipeline quality.

JUMPINGPOUND PLANTS

GAS PLANT

Construction on the Jumpingpound Gas Plant (see Figure 8) commenced in September 1950 and the plant went on stream in May 1951. The plant is located in the centre of the field, with 5 producing wells to the south of it and 6 to the north. The original plant sales gas capacity was 25 million cubic feet per day. Additional facilities were installed in 1952 which increased sales gas capacity to 35 million cubic feet per day. A further extension of plant facilities was completed in November 1954; it increased plant sales gas capacity to 60 MMcf/d.

The primary function of the plant is to produce a sweet dry gas of pipeline quality from a wet feed gas containing 3.5% hydrogen sulphide and 6.2% carbon dioixde. The well effluent from the field first passes through a central separator installation, where condensed

hydrocarbons and some of the water are removed from the gas (at a pressure of 800-1,000 p.s.i.). The raw gas then goes to the gas sweetening plant where the acidic constituents (H_2S and CO_2) are absorbed with an aqueous amine solution. The sweet gas then passes to the gasoline absorption plant, where natural gasoline is removed by absorption in 40° API oil. Finally, the remaining water is removed from the gas by means of a solid bed type (Sovabead) desiccant. The sales gas leaving the plant contains less than one grain of hydrogen sulphide per hundred cubic feet, and has water and hydrocarbon dew points below 15°F. This sweet dry gas then enters the sales gas line at pressures up to 750 p.s.i.

SULPHUR PLANTS

Construction on the original sulphur plant,the first of this kind to be built in Canada, was started in August 1951, and the plant went on stream in February 1952; plant capacity was 33 short tons of sulphur per day. An extension to this plant was completed in January 1955 with a capacity of an additional 55 tons per day; thus total sulphur recovery capacity is now 88 short tons per day. A railroad spur to the plant was put into service in February 1955, connecting with the Canadian Pacific Railway main line at Mitford. This line is used to move liquid products as well as sulphur.

In the sulphur recovery plants the acid gas effluent from the gas treating plant is processed to recover elemental sulphur. Briefly, the process consists of the combustion of one-third of the hydrogen sulphide in the sulphur plant feed gas to sulphur dioxide, which is then reacted catalytically with the remaining two-thirds of the hydrogen sulphide to form elemental sulphur. At Jumpingpound the sulphur plant feed gas contains approximately 38% hydrogen sulphide, and 85-90% of the potentially recoverable sulphur in the feed is recovered.

PRODUCTS MARKETING

The main plant product is the residue gas. This is sold to the local utility, Canadian Western Natural Gas Company, which operates a pipeline to Calgary and one to the Exshaw cement plant and Banff. The other products resulting from plant operation are disposed of in a variety of ways. Production of roughly 50° API condensate amounts to 9.3 bbl. per million cubic feet of raw gas. In addition, about 3.5 barrels of 68° API natural gasoline is produced for each million cubic feet of raw gas. These liquid hydrocarbon products are mixed and sold to a local refinery.

The hydrogen sulphide and carbon dioxide removed in the gas sweetening plant flows to two sulphur recovery plants were approximately 1.25 short tons of sulphur per million cubic feet of raw gas is produced. This sulphur originally went entirely to the Canadian pulp and paper industry, but is now sold to acid manufacturers near Edmonton and to uranium mining operations in northwest Saskatchewan.

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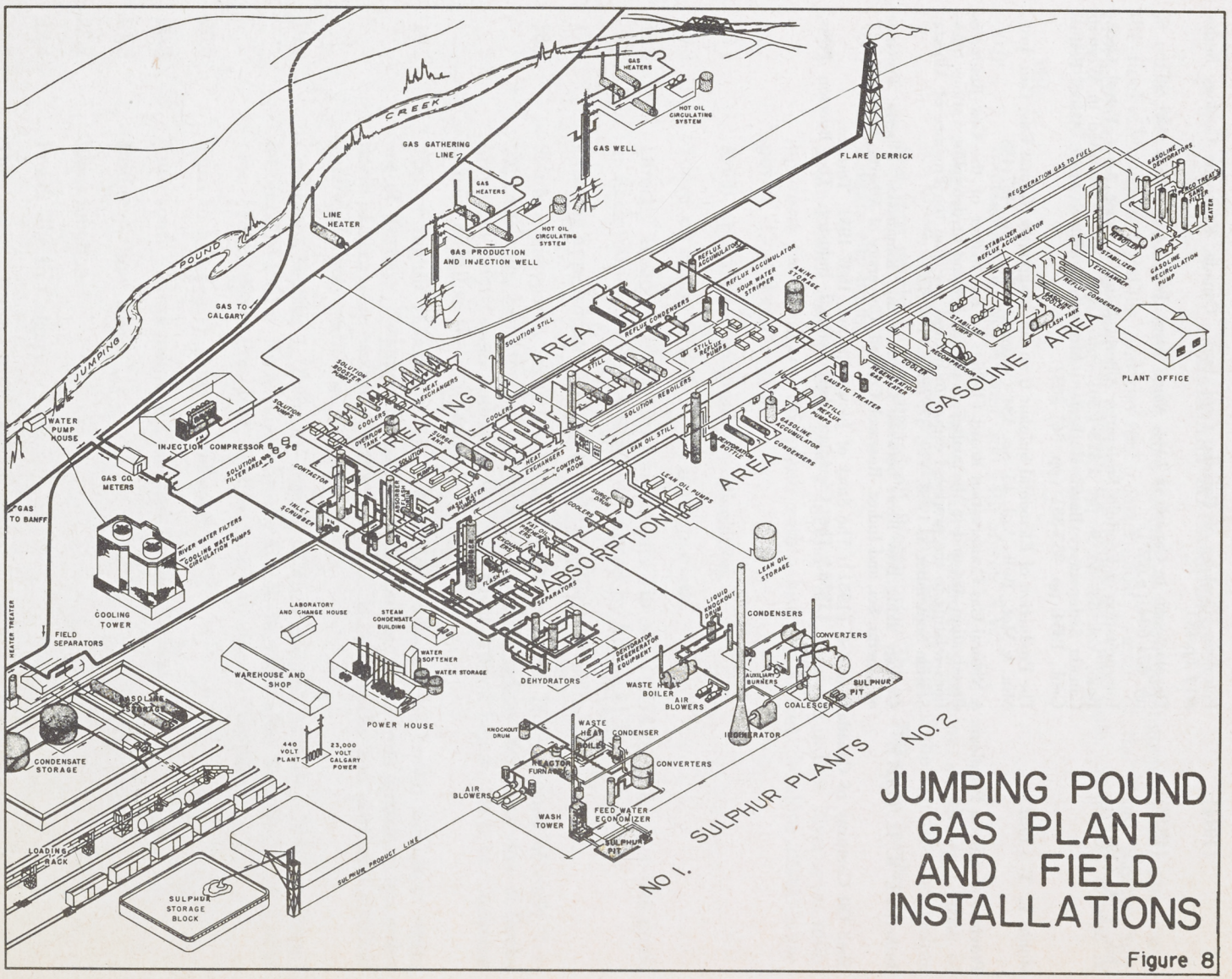
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JUMPING POUND GAS PLANT AND FIELD INSTALLATIONS

Figure 8

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ROAD LOGS

L. E. MARJANEN and W. SLEINKO[1]

CALGARY TO CANMORE

The first day's excursion route leads from Calgary via Shell Jumpingpound field. The Plains, the Rocky Mountain Foothills, and the first (easternmost) range of the Front Ranges Sub-Province rock exposures account for most of the geological time scale. Structures typical of foothills and mountain can be seen along the route.

Mile	
0.0	Intersection of 16th Avenue and 14th Street, N.W.
0 -	The route is underlain by early Tertiary Paskapoo sandstone, on the east flank of the broad, regional Alberta Syncline. This flank is part of the extensive homocline that dips gently southwestward off Precambrian Shield, 700 miles northeast.
3.0	Calgary city limits.
5.1	South-Branch road to Bearspaw Dam and Plant. Situated in Bow River seven miles upstream from Calgary, this plant, with a head of 50 feet, develops 22,000 horse-power. Completed in 1955.
5.1	Knob and kettle topography — glaciation.
6.3	Tower of station CHCT-TV on horizon south.
12.9	Directly ahead - Devil's Head or "Devil's Thumb" (9,174 feet), beehive-like dome in Rocky Mountain Front Range is capped by klippe of Palliser.
17.1	Crossing approximate position of axis of Alberta Syncline.
18.2	South - Viewpoint. Edge of Tertiary plateau (4,300 feet), formed of early Tertiary Paskapoo Sandstone in west limb of Alberta Syncline. Excellent view of Rocky Mountain front ranges and foothills, Bow River Valley below, town of Cochrane at base of hill to the southwest.
18.2	Top of Bighill (Cochrane Hill). Roadside exposures of brown sandstone strata are of Tertiary Paskapoo formation. Paskapoo sandstones from quarries a few miles north of here were used to construct the R.C.M.P. barracks and part of Canadian Pacific Railway station in Calgary.
19.9	Cochrane: Section 1, Twp. 26, Rge. 4, W5th Meridian. Altitude 3,748 feet. Population 530 (1951). Name given by the C.P.R. in 1884, after Senator M. H. Cochrane (1832-1903), President, British American Ranch Company.
20.0	Turn to left (east) along gravel road.
20.2	Turn south - cross mainline Canadian Pacific Railway.
21.3	Bridge — Bow River.
22.2	Road junction.
22.4	Power line to Calgary.
25.2	Turn west — Brushy Ridge School.

[1] The British American Oil Company Limited.

27.1 Junction of road – road to north is along the base of Towers Ridge – directly ahead is Jumpingpound Lake basin – across lake is Copithorne Ridge, composed of Belly River strata. Please refer to G.S.C. Map 653A – Jumpingpound.
Eastern edge of foothills – western edge of Plains.

27.5 Culvert – Towers Creek, approximate position of easternmost fault (Jumpingpound fault) zone of the foothills at this latitude – west dipping. Jumpingpound fault (Grande Valley fault of Wildcat Hills sheet) mapped by Henderson and North as a northern extension of the Turner Valley fault. (A.S.P.G. Field Conference, 1954).

28.0 Junction of road with south road; approximate position of fault that has carried Belly River on the west over Edmonton on the east.

29.0 Crest of hill – outcrop to right (north) basal Belly River, dipping 50 degrees east.
Valley of Jumpingpound Creek directly ahead.
Front Range of Rocky Mountains ahead on skyline.
Moose Mountain W. 35° S. (at "11 o'clock") – composed of Carboniferous strata – (Rundle).

29.1 Jumpingpound plant directly ahead.

29.2 Approximate position of Belly River - Wapiabi contact.

29.4 Road cuts – Wapiabi shale, dipping 35° to 50° east– in close proximity.

29.5 Shell Unit No. 5 to the right – North.

29.6 Bridge over Jumpingpound Creek.
Large cutbank exposure of Wapiabi to left.

30.1 Approximate position of fault contact, Blackstone over Wapiabi.
West dipping Blackstone on the west over east dipping Wapiabi.

30.4 Turn right (to the north) to Jumpingpound plant.

30.9 Large Wapiabi shale outcrops to east (right) in banks of Jumpingpound Creek.

31.0 Copithorne Ridge to east – Belly River capping ridge, Crawford Plateau directly ahead, Cope Ridge to left front ("10 o'clock").

31.3 Jumpingpound plant.

31.5 Wapiabi – West dipping in Pile-of-Bones Creek, creek bank to left.

31.6 Railway crossing.

31.8 Railway crossing.

31.9 Texas gate.

32.0 Texas gate.

32.0 Railroad Trestle-underpass.

32.2 Texas gate.

32.3 Turn to West-Texas gate (left).

33.0 Texas gate – Outcrop along road, Belly River. Cope Ridge (Belly River) to left.

33.3 Belly River sandstone, dipping 35° west.

34.0 Belly River outcrop.

34.0 Texas gate.

34.4 Power line in construction stage, Ghost plant to Calgary.

35.1 Power line (Calgary Power) — turn right (east). Radnor Plateau to north.

35.2 Top of hill — Cochrane ahead in distance. McLennan Creek in valley to left.

35.0 "Stock Promoter" to the left.

36.3 Texas gate.

37.0 Approximate edge of foothills.
Areas underlain by Paskapoo.
Power line to Calgary.
Jumpingpound Creek to right.
Paskapoo — gentle dips to east.

39.9 Bridge — beds of Paskapoo sandstone and shale in creek bed (Jumpingpound Creek).

41.1 Turn to left, (east).

41.5 Good view of west end of Bighill (Cochrane Hill) to left (north).

42.2 Turn to left — road to Cochrane.

42.7 Bridge over Bow River.

43.4 Southern outskirts of Cochrane.

43.8 Canadian Pacific Railway Mainline. Turn left (west).

44.1 Highway No. 1.

44.4 Western outskirts of Cochrane.

44.6 North — Paskapoo sandstone outcrop on hillside, in west flank of Alberta Syncline.

44.8 Bridge — Bighill Creek. Brick Plant.

45.3 Route from here to Mile 57.0 traverses the Jumpingpound Sheet — G.S.C. Map 635A.

47.4 Bridge — Horse Creek.

47.7 North — Outcrop on hillside of gently east-dipping (20°E.) Paskapoo sandstones, located in west flank of Alberta Syncline.
Directly ahead are the Wildcat Hills, foothills ridges, formed of inclined sandstones of Upper Cretaceous Belly River formation. Wildcat Hills in Blackfoot, "notayo-poyhsin".

49.3 Approximate position of Paskapoo — Edmonton contact.

49.8 Bridge crossing Grand Valley Creek. Left deformed strata of Upper Cretaceous, Edmonton and Belly River formations, exposed in channel, associated with an east dipping thrust fault, that marks eastern margin of Rocky Mountain Foothills Sub-Province at this latitude.

50.4 Approximate position of Grand Valley fault — west dipping, continuation of the Turner Valley and Jumpingpound fault —Belly River strata thrust over Edmonton.

52.4 South — Cairn commemorating plane crash of an American and Canadian airman. Cairn — Plaque — "This memorial is dedicated as a pledge of everlasting friendship to the U.S. of America, and to the gallant fighters of every state who joined

the British Commonwealth of Nations in the fight for democracy during the 2nd Great War".

Plaque No. 2 – "In this Valley two members of the R.C.A.F., Sgt. Pt. Alfred Regimbal, La Fleche, Sask. and his American comrade Ldg. Aircraftsman Quentin Burl Chace, Wichita, Kansas, were stayed by the hand of death. February 17, 1941".

52.5 Radnor Plateau to south (left) across Bow River.

52.9 Crossing the north end of the Jumpingpound field, Unit 13 (Lsd. 8, 16-26-5 W. 5th) can be seen directly south of the road, and Unit 14 (Lsd. 7, 21-26-5 W. 5th), the northernmost well in the field. is a short distance north of the road, hidden by the hillside.

53.7 Forestry Road to Nordegg.
North – Branch road to Ghost River Ranger Station. This road is part of system of Forestry roads that provide access to Clearwater Forest Reserve. Roads built by the Eastern Rockies Forest Conservation Board – a Federal and Provincial Agency.

54.0 Approximate position of a fault, Wapiabi shale over Belly River.

54.5 Power line.

54.7 Spencer Creek – culvert.

54.8 Devil's Thumb, good view – about "2 o'clock".

55.0 Ghost Power Dam. (Calgary Power). Belly River formation underlies the dam, Wapiabi is exposed about ⅝ mile downstream from dam, where it has been thrust over Belly River; fault downstream a few yards from where the Spillway runs into the main channel.
Ghost River Dam Plant at confluence of Ghost and Bow Rivers. Completed in 1929, plant has storage of 75,000 acre-feet, head of 75 to 110 feet, and capacity of 67,450 horsepower.

56.0 Ghost River Bridge.
Ghost River north– for about three-quarters of a mile flows along a fault contact between Wapiabi and Belly River.
Upper Cretaceous Wapiabi formation crops out in cutbank up-stream.
Ghost River: Dead Man River on Palliser Map, 1860; in Cree "Chi-pe-isi-pi", and in Stoney "winc-hin-ai-wap-ta", in Blackfoot "opskoonakaz", "river with rapids". A ghost was seen going up and down this river, picking up the skulls of the dead who had been killed by Crees. There are many Indian graves along the river. The combatants slain in a battle were buried in the woods on the top of Deadman Hill, which is between the Ghost and Bow rivers.
The Ghost River in preglacial time was the outlet for the Bow River, from Banff by way of Lake Minnewanka (J. A. Allan).
South – Gaherty Lake Reservoir Lake was named Gaherty Lake by J. A. Allan after G. A. Gaherty, President of Montreal Engineering Co. and Calgary Power Co. Ltd.

57.0 Entering Morley Map area, G.S.C. Map 777A.

60.5 Belly River strata exposed to the right (north).

60.7 Note terraces to right (north).

60.8 Right (north) – parts of an old cable tool rig, dating from Turner Valley days.

61.9 North – hillsides – a complex of faulted Cardium, Blackstone, and Wapiabi formations.

62.1 North — Road outcrop of Wapiabi shales with concretionary bands.

62.7 South — McDougall Memorial Church. Reverends George and John McDougall, father and son, missionaries of Methodist Church, ministered to Stoney Indians for 77 years.

Plaque — McDougall Church — "To the Glory of God and in the memory of Reverends George Milward McDougall and John Chantler McDougall, father and son, and their devoted wives, combined Ministry 77 years, pioneer missionaries of the Methodist Church to the Indians in Canada".
Plaque — "A Tribute to the Stoney Indians. They rendered unto Caesar the things that were Caesar's and unto God the things that were God's".
Plaque — "In affectionate remembrance of the Pioneers of Southern Alberta 'Well done Good and Faithful Servants'. Erected by the Southern Alberta Pioneers and Old Timers Association, July 1st, 1927".

62.9 East boundary of Stoney Indian Reserve. Ranching is chief occupation of Indians.

63.6 South — Morley Village. Indian Agency of the Federal Government, and Morley School for Indian children, operated by United Church of Canada, are situated here.

64.5 Roadside outcrops of Wapiabi shales.

64.7 - 66.0 Roadside and river channel outcrops of Upper Cretaceous Belly River sandstones and shales.

69.2 West — straight ahead. Good view of End Mountain (7,940 feet). In Fairholme Mountains. First Range of Rocky Mountain Front Ranges Sub-Province. The mountain, composed of strata of Fairholme, Ghost River, and Middle Cambrian formations, is folded synclinally and thrust over Upper Cretaceous Belly River beds.
Fairholme Mountains: 9,315 feet — on Palliser Map, 1850 ,named by Palliser after his sister Grace, who married 15th June, 1853, Wm. Fairholme, of Greenknowe, Berwickshire, Scotland.

73.8 Bridge crossing Oldfort Creek; channel is cut deeply in Wapiabi shales. Site of old Bow Fort is located on east bank of creek at its confluence with Bow River. Bow Fort was occupied by The Hudson's Bay Co. August 1833 to 5th January 1834. John E. Harriett was in charge. In the records of the Company it is called Peigan Post.

73.9 South — Gate to Camp Chief Hector, a boys' summer camp maintained for under-privileged youths by Calgary's Y's-men. The camp is named after Stoney Indian Chief Hector.

74.0 Belly River outcrop on hillside to right (north).

74.1 North — Good view of End Mountain syncline. Angular unconformity between Ghost River beds and underlying Cambrian.
Refer to L.M. Clark's Map, published in A.A.P.G. Rutherford Memorial Volume.

76.8 North (right) — Mt. Yamnuska; a fault scarp salient composed of precipitous Middle Cambrian thrust over Belly River shales and sandstones which underlie vegetation-covered slopes. The fault at base of cliff is in McConnell fault zone, easternmost Front Range fault. A subsidiary fault strikes through the saddle west Mt. Yamnuska, bringing Cambrian over Cambrian. The McConnell fault, originally mapped by G.S.C. geologist R. G. McConnell, is one of the first warped or folded faults described in North America. The fault (or fault zone) has been traced continuously from Highwood Pass northward to Wildhay River, a distance of more

than 250 miles. It marks boundary of Rocky Mountain Front Ranges Sub-Province on the west and Foothills Sub-Province on the east.

78.2 Turn to south (left) onto the branch road to Seebe and Kananaskis Dam. Seebe is northern terminus of gravelled road that leads 150 miles south through intermontane valleys to Coleman and Crowsnest Pass.

79.6 Seebe Dam and bridge over Bow River.
Dam is on Cardium formation – west dipping limb of north plunging anticline – Wapiabi formation upstream, Blackstone formation downstream.

79.7 Power plant – turn left after passing buildings.
Blackstone formation exposed in banks of Bow River to left (north).

80.3 Seebe residential area.

80.6 Cardium exposed in east limb of the north plunging anticline, and the west limb of the north plunging syncline.

80.7 Texas gate – top of Cardium formation.

81.6 Horseshoe Falls Power Plant, on Cardium formation.
Excellent exposure of Cardium formation in river bank.
Blackstone downstream – Wapiabi upstream.
Now retrace route to Highway No. 1.

85.6 Right (north) – cliff west of Mt. Yamnuska – lower cliff of grey weathering Cambrian – recessive break marks base of brown weathering Ghost River formation, which is overlain by dark grey weathering Upper Devonian Fairholme. Cliff forming Upper Devonian Palliser formation forms crest and western side of mountain.

87.9 Loder's Lime Plant – C.P.R. siding crossing. The plant's quarry is in pure limestone of Middle Cambrian age.

88.2 North – Orange-weathering band in small saddle is Ghost River formation. It is composed of black, grey and pink dolomite, and green and red dolomitic shale. The sequence, 170 feet thick, is unfossiliferous. At this locality it is underlain by Middle Cambrian carbonates and overlain by dolomites of Upper Devonian Fairholme formation, exposed in random outcrops in forested slopes, which is in turn overlain by grey Palliser cliff.

88.7 North – Ridge of light grey weathering Palliser limestone, outcrop at road level.

90.0 North (right) –Jura Creek valley, carved in basal Banff shales. Type section of Exshaw formation, of problematic Mississippian-Devonian age, is situated in west wall of creek about 1½ miles north.
North Banff-Rundle-Rocky Mountain sequence on mountain on north side of road from Jura Creek to Exshaw Creek.
North – Banff formation underlies forested slopes. Rocky Mountain formation and Rundle limestone exposed in Exshaw Creek, where the Exshaw fault has carried Palliser over the upper Rundle and Rocky Mountain formations.

91.1 Bridge crossing Exshaw Creek. Exshaw fault extends up tributary valley to the north (right).
South – Heart Mountain. Two branches of Exshaw fault are parallel to the lower and upper sides of massive limestone rib of Lower Rundle, which extends from base of mountain to peak. Synclinal drag fold in peak gives heart-like form.

91.3 Crossing Exshaw fault, a high angle, west dipping, thrust fault. Fault forms valley to the north and is seen at top of massive limestone in Heart Mountain.

91.4 Exshaw village, Twp. 24, Rge. 9, West of 5th Meridian; named after a son-in-law of Sir Sandford Fleming, director of the Cement Company operating here. Crossing Canadian Pacific Railway siding to Exshaw Plant of Canada Cement Co. Ltd.

91.8 North – Exshaw quarry above is in Palliser formation.
Road outcrop of massive limestone of Palliser formation.

92.1 North – Road outcrops of Palliser and Banff formations. Black shales exposed above contact are in basal Banff, not Exshaw.
Devonian and Mississippian contact hidden in curve of road.

92.4 Crossing surface trace of Lac des Arcs fault, a high angle west dipping reverse (overthrust) fault. Fault trace can be seen in gulley and near peak of mountain directly north. Lower Rundle limestone occurs in foot-wall near peak, and sequence of dark Cambrian limestones, brown Ghost River dolomites, and very dark Fairholme are seen in hanging-wall.

92.9 Lac des Arcs. The lake is an expansion of Bow River; arc is French for Bow; named by Bourgeau (1858).

93.4 North – Road outcrop of fossiliferous Fairholme dolomite.

93.5 Mt. Duncan M'Gillivray (name not official) directly ahead.
Rundle Cap forming prominent peak, underlain by normal sequence of Banff, Exshaw, Palliser, and a part of the Fairholme; Lac des Arcs fault repeats a part of the Rundle, underlain by Banff and Palliser down to the creek level.
Name Mt. Duncan M'Gillivray here proposed for the mountain south of town of Exshaw and between Heart Mountain and Pigeon Mountain after Duncan M'Gillivray – "wintering partners of the Northwest Company in the Saskatchewan district" who in 1801 "went overland from Rocky Mountain House to the Bow River between Calgary and Banff" –– "up the Kananaskis and over to the Spray, and thence through White Man's Pass to the headwaters of the Kootenay River" (J. G. MacGregor "Blankets and Beads" Institute of Applied Art Ltd., Edmonton, Alberta, 1949).

94.4 North (right) – Grotto Mountain (8,880 feet), named in 1858 by E. Bourgeau, Botanist, Palliser Expedition.
Rundle in crest, Banff slopes, Palliser cliff near base.

95.0 Rock wool plant, uses Lower Banff shales as raw material.

95.1 Gap Lake to south (left).
Pigeon Mountain to left across Bow Valley and west of Mount Duncan M'Gillivray. Peak is formed by Rocky Mountain formation, underlain by cliff of Rundle limestone; slopes in the Banff formation, with Palliser exposed in anticlinal core at the base.
Pigeon Mountain (7,855 feet) was named by Bourgeau 1858, probably after the wild pigeons seen in the vicinity.

95.6 Road outcrop of massive limestone of Banff formation.
Entering Cascade Coal Basin.

95.8 The Cascade Coal Basin lies in the inner foothills and extends for 45 miles in a northwest-southeast direction. The basin has an area underlain by coal – 32 feet

thick in aggregate – of 100 square miles, with a total of 2,228,800,000 tons (estimated reserves) of low volatile non-coking (steam)coal. The coal is on the Lower Cretaceous Kootenay formation. The present mining activity is on the western side of the valley.
Mountains on the south end of the Cascade Coal Basin are:
Pigeon Mountain (7,855 feet) on the east, capped by Rundle.
Mt. Allan (in the middle of the basin). The Mt. Allan syncline can be plainly seen near the crest.
Mt. Lougheed (10,190 feet), with rampart-like cliff of Rundle. Called Wind Mountain in the report on the Ribbon Creek Area by Crockford.
Route follows strike valley of Bow River; Fairholme Mountains on east, Rundle Range on west. Respectively these ranges are designated the first and second front ranges of Rocky Mountain Front Ranges Sub-Province. The U-shaped strike valley has been cut in Mesozoic strata in trough axis of Cascade coal basin.
Banff formation exposed in roadside exposures – good exposures along railroad cut on south side of road.

96.3 Rundle formation exposed in scattered outcrops from here to Canmore.

96.6 Solitary hoodoo halfway up the hillside to right.
Mt. Allan syncline to left (south) on Mt. Allan is plainly visible. The eastern horn of Mt. Allan shows the gently dipping east limb, and the western horn shows the overturned western limb. The Mt. Allan syncline extends northward from Mt. Allan, and is the dominant feature of the Cascade Coal Basin where the western limb is overridden by Palaeozoic strata thrust eastward on the Rundle-Cascade fault.
The Rundle-Cascade fault trace parallels the syncline axis a short distance to the west.
The west limb of the Mt. Allan syncline has been disturbed by a minor thrust fault, the surface trace of which is present between the syncline axis and the Rundle-Cascade fault.
Rundle-Cascade fault marks base of Palaeozoic rocks on the western (left) side of the valley. The fault plane dips west at angles varying from 30° to 75°; stratigraphic displacement is 8,000 feet or more but may be considerbaly less in the Mt. Cascade area.

96.9 Quarries in Rundle formation to the right.

97.3 Large cut banks of fluvial – glacial gravels.

97.5 Eastern cliff of the Three Sisters directly across the valley to the left, formed of the Upper Devonian Palliser formation – cliff reaches an elevation of 8,850 feet.
East – Fluvial-glacial sands and gravels.

98.3 Right – Brown weathering shales of Upper Rundle formation can be seen on upper slopes of Grotto Mountain and Fairholme Mountains.

100.9 Bridge.

101.3 West – Branch road to Canmore, a coal mining town of approximately 2,000 people. The coal seams are in Lower Cretaceous Kootenay formation.
West – Rundle Range; cliff along crest is formed of Rundle limestone, shale slopes below with medial limestone member are Banff formation, lower cliff is Palliser formation, forested slopes at base are underlain by Fairholme formation and rocks of Cambrian age. This range exhibits a structural-physiographic profile typical of the Front Ranges Sub-Province.

West — Road visible on mountain side leads to three Calgary Power Ltd. plants (hydro) completed in 1951. The Spray Lakes drainage system, located west of Rundle Range, has been diverted and forced to flow through a canal and pressure tunnel into Bow River at base of mountain road. A 2,151-foot hard rock tunnel, cut in Palliser and Fairholme limestones, which drops the water a vertical distance of 905 feet, produces 62,000 electric horsepower. An additional 27,000 horsepower are developed by the other two plants.

End of First Day's Excursion

CANMORE TO LAKE MINNEWANKA TO WHITE MAN GAP

The second day we will proceed from Canmore to Lake Minnewanka to White Man Gap. In part the route follows the strike valley of the Bow River with the Fairholme Mountains to the east and Mount Rundle to the west; the first and second ranges respectively of the Front Ranges Sub Province.

Mount Rundle is a west dipping block that has been thrust eastward on the Rundle-Cascade fault. The east cliff face, which is the face that parallels our route, is capped by Rundle formation, underlain by recessive Banff, cliff-forming Palliser, and recessive Fairholme.

The portion of the Fairholme Mountains that we see comprises a westward dip slope, with brown weathering Spray River shales near the base, underlain by the grey Rocky Mountain and Rundle formations, with brown weathering Banff near the crest.

Mount Rundle (9,338′), named by Hector (1859) after Rev. Robert Terrill Rundle, Methodist Missionary to the Indians of the North West (1840-48); the minutes of the Council of the Hudson's Bay Co., 1843, provide that a "commissioned gentleman's allowance" be paid to him; the name is on the Palliser Expedition map, 1859.

0.0 Junction of Highway No. 1 with branch road to Canmore.
Right: Hoodoos in glacial till, low on the bank of the terrace.
Left: "White Man Pass" — low pass between Mount Rundle to north and unamed peak to the south.
The name "White Man Pass", as used by D. J. McLaren in G.S.C. Bulletin No. 35, is at the southeastern end of Mount Rundle. White Man Pass as used by the Geographic Board of Canada is on Alberta-British Columbia boundary (approx. 50°45′N 115° 29′W) between Mount White Man and Mount Red Man, some 20 miles south of southeastern end of Mount Rundle. The Geographic Board is the authority and thus the common application of the name Whiteman Pass to the gap above Canmore is incorrect. The latter is properly called Whiteman Gap.

1.4 Canmore Ranger station to right.

2.5 Bridge.

4.2 East gate of Banff National Park.
Name taken from village of Banff, which was named by Lord Strathcona after a town near his birthplace in Scotland.
Banff National Park is the oldest of the National Parks in Canada, established in 1885, with an original size of 10 square miles that has grown to 2,564 square miles. It is the second largest park in Canada, exceeded only by Jasper National Park, 4,200 square miles.
Mount Rundle to left — note Park boundary slash in timber.

4.5 Cascade Mountain (9,836′) directly ahead, grey cliff above timbered slope is Palliser, overlain by recessive Banff, with Rundle at the crest. The lower Cretaceous Kootenay formation underlies the Palliser, below the Rundle-Cascade fault.

5.7 Carrot Creek bridge:
Upstream (right) — Mount Charles Stewart (9,315′) to right of gap, and Mount Peechee (9,625′) to the left.

5.7 Mount Charles Stewart — after Hon. Charles Stewart, Minister of the Interior, formerly Premier of Alberta.
Mount Peechee: named by G. M. Dawson (1884), after Sir George Simpson's half-breed guide during his trip across the continent in 1841.

7.1 Mount Norquay (8,275′), with ski slopes to left ("11 o'clock").
Stony Squaw (6,180′), directly ahead.

7.6 Tunnel Mountain (5,550′), directly ahead.

9.6 Note badlands (hoodoo-like) erosion of banks of till to the right.

10.3 Anthracite – old coal mining area active from 1885 to 1897.

10.5 Turn to right up Lake Minnewanka road.

10.8 Left: Lower Cretaceous Kootenay sandstones.
Johnson's Lake – Beaver dams and houses visible in lake to right.

10.9 Trail to Johnson's Lake.

11.2 Left – Fairholme Ranch.

11.5 Fernie shale exposed in road cuts.

11.9 Bridge over penstock to Cascade power house.
Head block to right, surge tower to left.
Kootenay formation exposed in rock cut.
Cascade Mountain at "11 o'clock".
Stoney Squaw Mountain at "10 o'clock".
Mount Norquay in background.
Mountains of Main Ranges visible in distance through Bow River gap, "9 o'clock".
Bourgeau Range "8 o'clock".
Sulphur Mountain.
Mount Rundle "6 o'clock".
Low foreground at "8 o'clock" on fluvio-glacial gravels, with hoodoo-like forms developing.

12.5 Right: Canal to head of penstock from Lake Minnewanka.

12.7 Mount Aylmer (10,375′) directly ahead – in the south end of the Palliser Range and north of Lake Minnewanka.
Mount Aylmer was named in 1890 by J. J. McArthur, D.L.S., after his native town, Aylmer, Quebec.

13.3 Note slack heap on side of Cascade Mountain directly ahead. Old mine dump from early Bankhead days.

13.5 Two Jack Camp ground.

14.2 Mount Inglismaldie (9,725′) ahead and to the right, on the south side of Lake Minnewanka, marks north end of the Fairholme mountains.
Capped by Rundle - Banff and Palliser and Fairholme in a broad anticlinal structure, visible from Lake Minnewanka.
Mount Inglismaldie named by George Stewart, Superintendent of Rocky Mountains Park, in 1886 or 1887, after Inglismaldie Castle, Kincardineshire, Scotland, seat of the Earl of Kintore, who visited Banff at that time.

14.4 Triassic Spray River formation exposed in road cuts to the left.

14.6 Lake Minnewanka directly ahead – control gates to the right in valley.

14.7 Outcrops of Permo-Pennsylvanian Rocky Mountain formation – mostly quartzite and siliceous dolomite beds for next half mile.

15.3 Earth fill diversion dam.
Lake Minnewanka was raised from an elevation of 4,769′ to an elevation of 4,840′ (71′) by building the dam; its waters are used chiefly for power development.
At "3 o'clock" Cascade Mountain. The Rundle-Cascade thrust fault moved Palliser beds in the hanging-wall directly on Kootenay beds in the foot-wall. This can be seen, with grey Palliser limestones lying directly on dark Kootenay sandstones and shales. This differs from Mount Rundle, which is in the same fault slice, in that Mount Rundle has a large Fairholme section below the Palliser.
Coal seams in these Kootenay beds have been mined, and slack heaps are present at the base of Cascade Mountain.

At "1 o'clock" unnamed mountain in background is composed of Triassic Spray River formation overlain by Rocky Mountain formation. A back limb fault repeats the Spray River and Rocky Mountain formation, which can be seen in grey-brown-grey weathering colours.

Lake Minnewanka was so named by the Department of Interior in 1888, to replace the then existing name Devil's or Devil's Head Lake. Minnewanka means "lake of the water spirit". Formerly called Devil's Lake or Cannibal Lake in Stoney, or Long Lake in Cree. Sir George Simpson named it "Peechee Lake" after his guide, but, as this name had not appeared on any map or obtained any currency, G. M. Dawson reapplied it to a mountain south of the lake.

15.5 East Mount Costigan (9,775′) in distance.

15.7 Spillway.

Delegates will debus and proceed on foot down the Cascade River channel to old town site of Bankhead, where the buses will be waiting.

Below the spillway gates is the Triassic Spray River - Permo-Pennsylvanian Rocky Mountain contact.

Please be careful — do not step on the mud banks at the end of the chute.

The lower half of, and a dolomitic limestone at the top of the Spray River are well exposed in the valley. Dowling (1912) measured 1,300 feet of Triassic in this vicinity, Crockford measured 600 feet of Triassic on Evans-Thomas Creek 28-30 miles south, and Mackay measured 1,100 feet in Canmore area.

The Triassic-Jurassic contact is not exposed, but there are excellent exposures of Jurassic Fernie shale.

Dowling measured 1,600 feet in 1912, MacKay measured 1,200 feet in Canmore area, and Crockford 1,100 feet in the Ribbon Creek area. The 1,600 foot thickness measured by Dowling may be slightly greater than the actual thickness, as there are contortions and faults.

The lower part of the Kootenay (lower ribboned sandstone) is very nicely exposed at the old mining centre of Bankhead. The lower ribbon sandstone as measured by Dowling is 1,100 feet thick.

17.4 Bankhead: named by Lord Strathcona (1905) after Bankhead, Banffshire, Scotland.

18.4 Road. Junction with main road.

18.9 National Cadet Camp.

19.1 Right — Banff landing strip.

19.5 Cross Trans-Canada Highway.

19.7 Cross main line Canadian Pacific Railway.

20.4 Junction with Highway No. 1. Proceed to Banff.

21.6 Banff town.

22.2 Turn left on Moose Street (left side of school).

22.4 Turn left up the hill.

22.7 Rundle limestone outcrop.

23.1 Beckers Bungalows.

23.8 View of Mount Rundle to right. Golf course in valley.

Tunnel Mountain to the west. Hoodoos at the base of ridge to the east.

Fairholme Mountains to the east across the Bow Valley.

24.5 Bow River and hoodoos to right.

24.6 Junction. Turn left.

26	Dry stream channel.
26.1	Canadian Pacific Railway crossing and junction with Highway No. 1.
29.4	Good view of Three Sisters ahead. Mount Lougheed in background beyond the Three Sisters. Mount Allan directly ahead. Note Mount Allan syncline.
30.5	Carrot Creek bridge.
32.0	Banff Park exit.
33.8	Bridge. Excellent view of Three Sisters, Mount Lougheed, Mount Allan directly ahead.
36.4	Canmore. Turn right. Canadian Pacific Railway crossing.
36.8	Bridge over Policeman Creek.
36.9	Canmore: The name may be after Malcolm Canmore, a Scottish king.
37.4	Bridge, Bow River.
37.8	Rail crossing. Canmore mines office and Opera House.
37.8 - 38.7	Kootenay coal measures exposed. Site of the No. 1 Mine – some building remains can be seen to left of road.
	Canmore Creek to left.
	South (left) – The Rundle-Cascade fault trace is clearly visible at the base of easternmost peak of the Three Sisters – Palliser over Kootenay.
37.9	Junction. Keep to right up Spray Lakes Road.
39.2	Top of penstock for lower Power house and end of lower canal.
39.9	View of Spray plant and diversion canal to lower left.
40.1	Road junction. Spray plant to left. Keep right.
40.6	View of mountain to left with Palliser, Fairholme, Ghost River, and Cambrian exposed. Prominent brown band low down is Ghost River.
41.1	Cambrian exposed on right at base and overlain a few feet above by Ghost River.
41.4	Good view of falls to lower left, over Ghost River beds.
41.6 - 41.9	Exposure of lower Fairholme (Cairn formation) on right road cut.
41.9 - 42.1	Southesk formation of Fairholme Group, notice fold on mountain to south.
42.4	Alexo formation, small outcrop.
42.6	Bow River Forest Reserve Gate. Palliser Formation. Goat Range ahead.
	Delegates will leave the buses and walk down the hill to the end of the Devonian exposures, where the buses will be waiting.

Acknowledgments — In the preparation of the above road logs liberal use was made of previous road logs in the Bow River Valley area prepared by Shell Oil Company of Canada Limited and Canadian Gulf Oil Company. Much of the detail on geographic names is from "Place Names of Alberta", published in 1928 by the Geographic Board of Canada..

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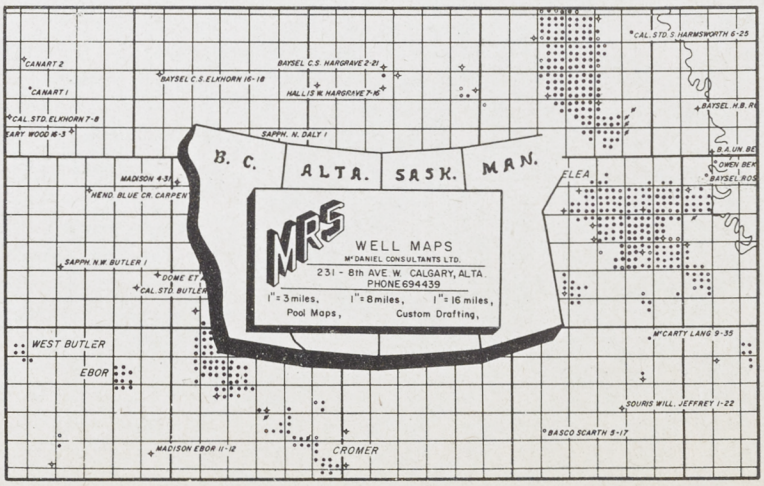
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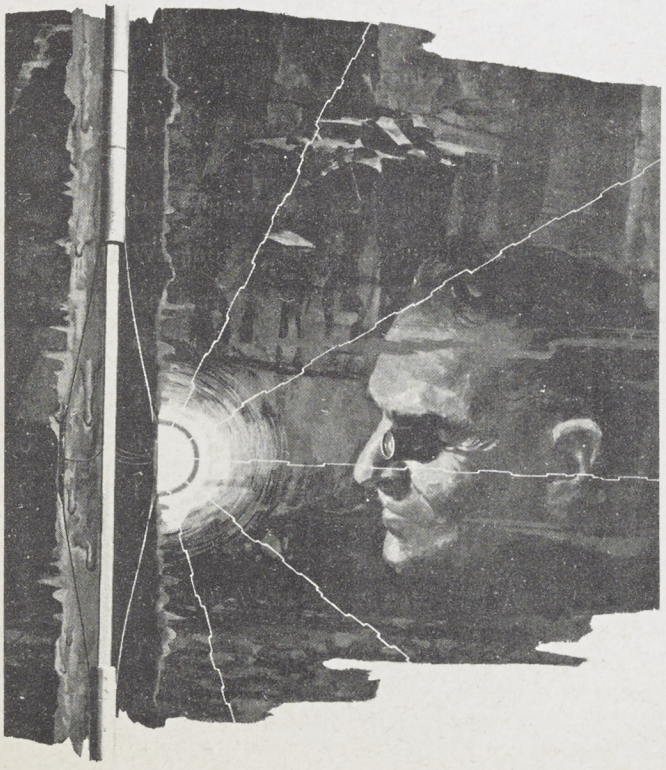
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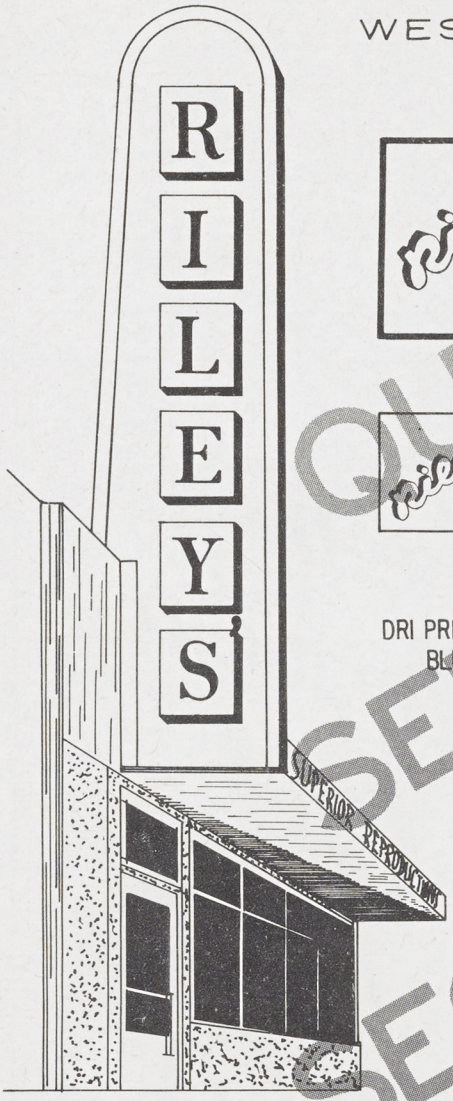
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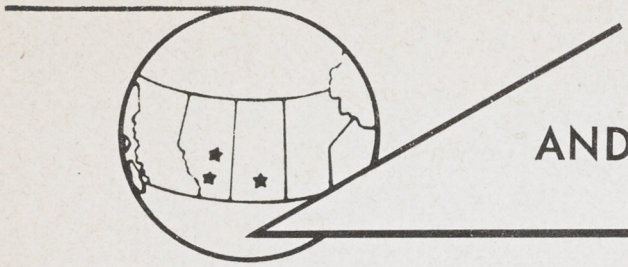
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